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RADAR TARGET SCATTER SITE (RAT SCAT) VHF DEMONSTRATION PROGRAM

Dr. Charles C. Freeny
General Dynamics

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RADAR TARGET SCATTER SITE (RAT SCAT)
VHF DEMONSTRATION PROGRAM

Dr. Charles C. Freeny
General Dynamics

AFLC, GAFB, N.Y., 10 Apr 67-106

FOREWORD

This report is a documentation of the second phase of a two-phase program designated to investigate the feasibility of making VHF Radar Cross Section measurements at RAT SCAT. The first phase was reported in Technical Report No. RADC-TR-66-215.

This work was sponsored by the Space Surveillance and Instrumentation Branch of Rome Air Development Center. The investigation was conducted by the Fort Worth Division of General Dynamics with the major portion of the tests being conducted at RAT SCAT under Contract AF30(602)-3815. This work was conducted under the auspices of D. M. Montana and the report was prepared by C. C. Freeny of the Fort Worth Division. This report is General Dynamics Report No. FZE-615. Project No. 6503

Release of subject report to the general public is prohibited by the Strategic Trade Control Program, Mutual Defense Assistance Control List (revised 6 January 1965), published by the Department of State.

This technical report has been reviewed and is approved.

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ABSTRACT

The material presented herein are the results obtained from the successful demonstration of the feasibility of making radar cross section measurements in the VHF band at the Radar Target Scatter Site (RAT SCAT), White Sands Missile Range. Included herein are the results of a Phase Two Field Demonstration program conducted in the 30- to 100-megahertz band for the purpose of evaluating (1) the feasibility of using the electronic systems, built during this program, at RAT SCAT in the VHF band, and (2) the range geometry configurations resulting from the Phase I Computer Study program relative to their utility in an operational system which could be implemented at RAT SCAT.

A test program was defined by which the electronic system, antenna system, range designs, and target supports were evaluated. The coherent electronic system design was such that both CW and pulsed operation was possible. The design included a RF cancellation network for CW short range operation and an IF cancellation network for pulsed operation at longer ranges. Both a single antenna-hybrid system design for use with a short range design and a dual-antenna system design for use at the longer range were implemented and tested. A range length of 350 feet was used to evaluate the short range CW cancellation technique and a range of 1500 feet was used to evaluate the pulsed technique. Test frequencies of 30, 45.5, 61.1, and 92.2 megahertz were used to obtain information relative to (1) transmitter and receiver performance, (2) single antenna hybrid isolation, (3) dual antenna isolation, (4) RF field gradients, (5) background levels, (6) cross section measurement capability, and (7) feasibility and requirements for adopting the electronic system and range designs into an operational system at RAT SCAT.

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EVALUATION

RAT SCAT, a static radar cross section facility, located at the White Sands Missile Range had been developed under AF30(602)-2831 for the measurement of full scale aerospace vehicles in the frequency range 100 to 12,000 megahertz. This facility was designed to take advantage of dielectric ground plane reflection phenomena to provide necessary isolation of the illuminated target and the local environment. The resulting vertical field pattern as acted upon by the complex reflection coefficient of the ground plane is inherently best suited to measurements performed at frequencies above the VHF range. At frequencies above 1000 megahertz the complex reflection coefficient approaches a value of minus one for low grazing angles and is independent of polarization. Degradation in performance of the ground plane range increases with decreasing frequency and becomes very severe in the VHF band and especially at frequencies below 100 megahertz, where both the magnitude and the phase angle of the reflection coefficient become increasingly dissimilar for the vertical and the horizontal polarization cases. Other phenomena occur at frequencies below 100 megahertz which further complicate the problem. These are the existence of a large vertical polarization surface wave component and target-to-ground plane coupling produced by the horizontal polarization induction field. Further, for both polarizations, isolation requirements impose severe restraints on range configuration.

This investigation has considered the effects of all of these factors first by a feasibility study (reference Interim Report RADC-TR-66-215) and subsequently by a field demonstration and evaluation of the two range configurations which were recommended as a result of the feasibility study.

This contract effort achieved a significant breakthrough in range measurement technology producing for the first time valid radar scattering matrix measurements in the 30 to 100 megahertz frequency range.

Donald M. Montana
DONALD M. MONTANA
Contract Engineer

SECTION 1

INTRODUCTION

This technical documentary report contains a description of the VHF (30 to 100 megahertz) demonstration program conducted at the Fort Worth Division of General Dynamics and RAT SCAT, together with results and recommendations.

The primary objective set for this phase of the VHF program was to demonstrate that a coherent electronic system could be built for making valid radar cross section measurements at the RAT SCAT facility. Prior to the demonstration program, a VHF feasibility program was conducted and the results reported in Reference 1. The information obtained from the feasibility study was used to select the range and system configurations evaluated during the demonstration program. The two basic system configurations evaluated during the demonstration program were (1) a short-range, CW, RF cancellation system and (2) a long-range, range-gated, IF cancellation system. The results of the test program indicate that the range-gated system is the more desirable of the two configurations in terms of measurement capability and operational convenience. Also, the information obtained from tests by using the range-gated configuration indicates that if minor changes are made in the electronic and antenna systems, along with an optimum choice of target ranges, a fully operational system can be implemented at RAT SCAT to cover the 30- to 250-megahertz frequency region. The location of the VHF range relative to the existing RAT SCAT operational ranges is in Figure 1.

In Section 2, the equipment and the range configurations implemented and evaluated during the demonstration program are described. A detailed description of the electronic system is included in Reference 2 whereas Section 2 contains only a conceptual type description. Section 2 also contains a description of the antenna, rotator, and target supports used during the demonstration program.

In Section 3, the test program conducted at the RAT SCAT site is described in terms of the equipment tests and the range tests.

In Section 4, results from the test program conducted at the RAT SCAT site are presented, along with a discussion of the implications derived from the test results relative to an operational measurement system.

In Section 5, the results of the test program are summarized; and on the basis of these results, recommendations for improvement are presented relative to implementing a fully operational cross section VHF measurement system at the RAT SCAT site in the 30- to 250-megahertz region.

SECTION 2

DEMONSTRATION EQUIPMENT AND RANGE DESIGN

2.1 General

On the basis of the results of the VHF feasibility study (Reference 1), an electronic system capable of being operated in the CW and the pulsed modes was designed for use with a short-range, CW, cancellation measurement technique and a range-gated measurement technique at a relatively longer range. These two range designs were selected since the RF field probe data (theoretical and measured) in the VHF region of 30 to 250 megahertz indicated that acceptable field gradients for obtaining valid radar cross section data could be achieved in conjunction with practical antenna heights. Although the field probe data obtained during the feasibility study indicated that range lengths in the 300- to 2500-foot ragion would yield acceptable field gradients for targets between 15 and 70 feet in length, a short range and a long range were selected in order to evaluate the electronic system and rotator design. The short range was selected to be similar in length to the range used during the feasibility study in which a CW cancellation system was used. The long range was selected on the basis of achieving an optimum trade-off between measurement sensitivity (closer range) and system recovery time (longer range); however, information as to system recovery time was not available prior to the demonstration test program. The rotator design demonstrated was of such a nature as to minimize the reflections from the rotator pit in the case of vertical polarization. The target supports were similar to those used in the feasibility study in that hollow fiberglass cylinders were used.

2.2 Equipment Design

Presented below is a qualitative description of the electronics system design implemented for the VHF demonstration program. A detailed quantitative description of the electronic system is presented in Reference 2. In Figure 2 a schematic of the system configurations evaluated during the demonstration program is presented. The RF cancellation network was used with

the single-antenna CW cancellation configuration and the IF cancellation network was used with the dual-antenna pulse system configuration. This subsection also contains a description of the basic design of the transmitter, the receiver (including cancellation network), and the antenna systems.

2.2.1 Transmitter

The transmitter design was such that 200 watts could be transmitted by using pulse widths between 0.5 and 30 microseconds (CW) in the 30- to 100-megahertz region. In addition, the system design had to be such that amplitude and phase variations were sufficiently small as to allow a cancelled background signal operation over a period of time up to several hours. The design chosen to meet these requirements is shown in Figure 3. As indicated in the figure, the coherent operation is achieved by deriving the transmitted RF signal from a Manson Lab MHS-400 frequency synthesizer, along with the appropriate frequency multiplier units. The synthesizer unit is used to derive both the LO signal and the IF cancellation signal, as well as the RF signal. The IF signal is 15-megahertz; this value is considerably below the operating frequency range of interest. The transmitted signal is obtained by mixing a synthesized signal with a 15-megahertz synthesized signal and filtering the resultant to produce the desired RF signal. The resultant RF signal is then pulsed and amplified to approximately 1 watt in the driver circuit to produce the desired pulse width. The output of the driver is again amplified in the final amplifier and transformer coupled to the transmitter line.

2.2.2 Receiver

The receiver design is shown in Figure 4, along with that of the RF and IF cancellation networks and a portion of the phase measurement system. As indicated in the figure, the receiver is basically that of a superhetrodyne type with the addition of an RF preamplifier to decrease the noise figure. Also the receiver is provided with three IF amplifiers of bandwidths .2, .5 and 2 megahertz centered about a frequency of 15 megahertz. In order to operate the VHF system in conjunction with the existing RAT SCAT cross section and phase consoles which operate at 60 megahertz the 15 megahertz IF signals sent to these phase consoles are translated to

60 megahertz. In order to enhance recovery, the receiver is provided with a blanking circuit which allows the LO signal to be attenuated until the initial pulse energy has dropped below the RF and/or IF amplifier saturation levels. A 60-db switch is provided to achieve a sufficient amount of attenuation.

The RF cancellation network depicted in Figure 4 includes a motor controlled phase shifter, along with a set of fixed phase shifters. The amplitude controls likewise consists of a vernier adjustment and a step attenuator. The IF cancellation network consists of a pulse width and shaping network in addition to a time delay and attenuation network.

2.2.3 Antennas

The design for the single and the dual antenna system is shown in Figure 5. The basic antenna is a five-element Yagi of which two were constructed at each of ten frequencies covering the 30- to 100-megahertz. The use of this type design allows a relatively high gain to be obtained (10 dB above isotropic) by employing a relatively small antenna as compared to, for examble, a log periodic or parabolic antenna.

The antennas are attached to base plates which are mounted on steel triangular radio towers 60 feet in height. The base plate can be positioned at any height within this 60 feet by using a rope and pulley system. To support the front of the antennas and stabilize the system, three ropes are attached to the front of the antenna as indicated in Figures 5(a) and 5(b). The front support rope is also threaded through a pulley at the top of the tower and used in the raising and lowering operations.

In order to operate by using a single antenna, a hybrid box was attached to one of the towers as indicated in Figure 5(a). The hybrid box consisted of two sets of hybrids covering the frequency range of 30 to 60 and 60 to 120 megahertz, respectively.

In addition, the hybrid box housed a coupler with which to obtain the RF cancellation signal and a dummy load with which to terminate one port of the hybrids. The basic hybrids were designed to allow 60 dB of isolation between the transmitter port and the receiver port, the actual depending upon the VSWR looking into the antenna port.

For the dual-antenna operation, two sixty-foot towers were provided, along with mounting pads spaced 130 and 160 feet apart. With this amount of separation it is possible to use the ground plane effect to obtain a greater amount of isolation than that achievable by use of the same separation in free space.

2.3 Range Design

To obtain valid cross section measurements in the VHF region, a range design must be chosen on the basis of several factors which are not prevalent at the higher frequencies. The most significant factors are (1) that practical antennas tend to be isotropic and (2) that a vertically polarized signal radiates so as to produce a significant field intensity at the surface, the exact amount depending upon the surface material and topological conditions. These two conditions require certain precautions to be taken in the VHF region which are not necessary at the higher frequencies (e.g., in the design of the pit rotator and the antenna system). Also there are certain advantages in using the VHF region rather than the higher frequencies, such as the fact that larger target supports can be used and that the use of longer wave lengths makes the employment of an outdoor background cancellation approach feasible.

During the feasibility study (Reference 1), such problems and advantages were investigated, along with the RF fields as a function of range, frequency, and soil conditions; and on the basis of the results of that study, two range designs were chosen for demonstrating the feasibility of using either a CW cancellation system or a range-gated system. The CW cancellation system would involve a shorter range separation between antennas and target whereas the range-gated approach would involve a greater separation. During the feasibility study, a CW cancellation system was demonstrated in which two antennas were used to achieve the necessary sensitivity in terms of dBsm. However, it was noted that because of the relative short range, this technique produced a rather large bistatic and tilt angle which caused noticeable errors in the data when the target lengths exceeded about 20 feet. For this reason, a single-antenna system in which a hybrid would be used to achieve isolation and eliminate the bistatic angle was chosen for evaluation during the demonstration phase of the program. Also it was planned to use a shorter target

support to reduce the tilt angle. This system is described in paragraph 2.3.1 in terms of the range length, required antenna isolation, antenna, and target heights.

During the feasibility study at RAT SCAT, it became apparent that the soil properties and availability of relatively smooth terrain, would possibly allow a range gated system to be operated in the VHF region. If the utility of this approach could be demonstrated, several advantages would be gained over the use of the CW system in both the area of measurement capability and the area of operational techniques. The long-range design is described in paragraph 2.3.2.

One of the advantages of making cross section measurements in the VHF region is that larger target supports can be used relative to those required at the higher frequencies. Hollow fiberglass columns appear to be quite suitable on the basis of their backscatter characteristics and their load-bearing capabilities. These columns are discussed in paragraph 2.3.3, along with the low backscatter pit-rotator design.

2.3.1 Short Range Design

The short range design was such that the rotator pit was placed 350 feet from the antenna tower. When this range length and the 60-foot tall antenna tower are used, cross section measurements can be made by employing a target support only 25 feet high rather than the taller supports required at the longer ranges. The required antenna heights for operation at the 350-foot range in conjunction with a 25-foot column are shown in Figure 5 in the case of vertical and horizontal polarization. The field gradient criteria used to arrive at the data in Figure 6 was that the vertical one-way amplitude and field gradients should not be greater than 1 dB and 180/8 degrees respectively over a 6-foot region centered about the target.

In order to achieve a sufficient amount of cross section measurement sensitivity together with a realistic amount of cancellation, it is required that a minimum level of isolation be achieved between the transmitter port and receiver port of the hybrid. On the basis of the results obtained during the feasibility study, it was anticipated that 40 to 60 dB of stable cancellation could be achieved by using the demonstration equipment design to be implemented. The larger amounts of cancellation

were expected at the lower frequencies (30 to 60 megahertz). On the basis of these values of cancellation 60 @ 30, 55 @ 60, and 45 @ 90 megahertz) and the field probe data computed for the optimum antenna heights within the constants shown in Figure 6, the data in Figure 7 indicates the amount of isolation required to achieve a given amount of cross section measurement sensitivity.

On the basis of the data in Figure 7, it can be seen that a hybrid system capable of producing 40 to 60 dB of isolation would be necessary for the single-antenna system approach to be a realistic technique.

2.3.2 Long Range Design

Results from the feasibility study were used (Reference 1) to define range limits within which valid cross section measurements could be obtained in the VHF region by using antenna and target heights in the region below [illegible]0 feet, along with anticipated power and antenna gains. The limits established were also based on the requirement that the same antenna height could be used for both vertical and horizontal polarizations and that use of the electronic antenna system would allow complete recovery of the receiver system in four times a pulse width of .5 microsecond (1000 feet). On the basis of the above constraints, a long range pit could be placed between 1000 and 2500 feet; and the measurement sensitivities would be near those indicated in Figures 8 and 9 for the case of vertical and horizontal polarization, respectively.

Since a system recovery time of 1000 feet was felt to be somewhat optimistic at the lower frequencies a range length of 1500 feet was chosen to be evaluated during the demonstration phase of the program in order to achieve as much sensitivity as possible. Results obtained from the demonstration program by using this range length could then be used to establish a more optimum pit location(s) if necessary.

For the 1500-foot range, the expected field gradients (computed for normal soil moisture conditions) were computed by using the RADC CDC 1604 computer. These data are presented in Figures 10 and 11 for the case of horizontal and vertical polarizations, respectively. The data in Figures 10 and 11 are all representative of the case of a 48-foot antenna height, and the zero reference corresponds to twice the maximum field intensity produced by the antenna in free space.

Figure 5(b) contains an illustration of the antenna configuration used in the long range design in which tower separations of 130 and 160 feet were available. On the basis of theoretical considerations and results obtained during the feasibility study, these two separations would allow greater than 40 dB of isolation to be achieved at all frequencies in the region above 30 megahertz, and with both vertical and horizontal polarizations. In addition, these separations are sufficiently small as to allow operation at bistatic angles no greater than approximately 6 degrees when the 160-foot antenna separations are used and tilt angles less than 2.5 degrees when a 65-foot target height is used. On the basis of the cross section measurements made during the feasibility study, these sizes of bistatic and tilt angles will not produce a significant error between the data so obtained and that which would be obtained in the monostatic case.

2.3.3 Target Supports

The target supports used during the demonstration program were similar to the type used during the feasibility study (Figure 12). Several columns of the type shown in Figure 12 were constructed during the demonstration program in order to provide target heights between 15 and 65 feet.

The rotator pit design implemented at the 350- and 1500-foot ranges are illustrated in Figure 13. The rotator was a Scientific Alanta rotator capable of supporting 4000 pounds. A rotator driver unit was designed to allow a monotonic increasing (decreasing) acceleration (deceleration) of the column and target up to (down to) a constant preselected angular velocity.

The rotator pit was designed to provide a minimum discontinuity at the surface by (1) making the pit of as small a diameter as practical and (2) providing pit covers to obtain a smooth surface with the exception of the ring discontinuity between the covers and the column base. On the basis of the vertical field intensity at the surface in the VHF region, such a pit design is necessary to minimize the pit backscatter.

SECTION 3

DEMONSTRATION PROGRAM

3.1 General

Delineated in this section is the test program conducted at the Radar Target Scatter Site (RAT SCAT) in order to demonstrate the feasibility of making radar cross section measurements at RAT SCAT in the VHF region (30 to 100 megahertz) by using the equipment and technique developed by the Fort Worth Division for RADC under Contract AF30(602)-3815. The location and particular range design to be demonstrated under this program were derived from results obtained from an analytical and measurement program conducted earlier in the program (Reference 1). The results obtained from the test program defined in this section, along with results from additional tests conducted during the demonstration test program, are discussed in Sections 4 and 5.

The test program encompassed two basic types of demonstration tests. One group of tests was designed to demonstrate the performance of the electronic systems and the other to demonstrate that the selected range geometries and target support techniques designed and developed for VHF measurements at RAT SCAT will allow high-quality cross section data to be obtained on an operational basis. The tests were designed to obtain a sufficient amount of data to demonstrate system performance throughout the VHF band (30 to 100 megahertz). In addition, it was originally planned to perform selected measurements above 100 megahertz to demonstrate that the system design and range geometries selected for the VHF region can be extended to the present RAT SCAT Band 1 frequency to achieve increased cross section measurement capabilities. However, because of the power limitations in the VHF equipment above 100 megahertz and because unforseen factors arising during the test program needed investigating, tests above 100 megahertz were not conducted.

Tests were conducted at four frequencies nominally (30, 45, 60, and 90 megahertz) and for both horizontal and vertical polarization. The exact frequencies were selected on the basis of optimum RFI and antenna match considerations. Amplitude and phase measurements were made at each of these frequencies. Calibration targets included dipoles, hoops, and spheres (when background permitted) and specific targets measured were cylinders 20 and 40 feet in length constructed by welding oil drums end-to-end. These cylindrical targets were measured previously and the results compared with scale models constructed and measured at the RAT SCAT facility by using a scaled frequency. The results from the previous measurements indicated that the semi-discontinuity created by spot welding the barrels together did not niticeably alter the cross section from that which was achieved by using the continuous cylinders (scale models).

The electronic system performance was demonstrated at each of the four lower frequencies in terms of (1) output stability; (2) PRF, pulse shape, and coherency; (3) line loss; (4) receiver sensitivity and noise figure; (5) recovery time; and (6) compatibility of phase measurement provisions with existing RAT SCAT phase recording system. In addition, tests were conducted to determine the amount of antenna isolation which could be achieved at each of the test frequencies, as well as tests to determine the background which can be achieved by using the long-pulse cancellation approach (short range) and short-pulse cancellation approach (long range). At the longer range, it was potentially feasible to measure the cross section of the target support and such a test is reflected in the test program.

The location of the VHF range is indicated in Figure 1, as well as the location of the range relative to the existing measurement facilities. The two range lengths used were chosen on the basis of rationale discussed in Section 2. Also discussed in that section were the single-antenna and hybrid system to be used at the short range and the dual-antenna system at the long range; it was also noted that two spatial locations for the dual-antenna system were constructed at the site. The use of one location allowed a 130-foot antenna separation; the other, a 160-foot antenna separation, with antenna heights continuously adjustable up to approximately 60 feet. This versatility in the antenna system was to be used to achieve an optimum of RF field isolation between transmitter and receiver antennas.

To perform the test program as outlined, equipment from the present RAT SCAT complement was required in addition to the VHF equipment fabricated under the program being reported. This additional equipment includes such items as : an equipment van, a portable power unit, a RAT SCAT control console, a RAT SCAT phase measurement console, analog recorders and target handling equipment.

The test program is presented under two classifications referred to as system tests and range qualification tests. The system tests are grouped in terms of those needed to determine the performance of (1) the transmitter, (2) the receiver and antenna system, and (3) the phase measurement capability. The range qualification tests are grouped in terms of those needed to determine performance in the areas of (1) antenna configuration, (2) field gradients, (3) calibration targets, (4) background and target supports, and (5) cross section measurements.

3.2 System Tests

The system tests were designed to obtain information as to the basic operational suitability of the electronic equipment constructed during the program being reported. Although certain minor modifications of the electronic equipment are recommended in Section 5 in order to obtain a system optimized for pulse operation, the basic results (see Section 4) from the tests described below indicate that the electronic system, as designed and constructed, is an operational system.

3.2.1 Transmitter

In order to ascertain the performance of the Transmitter design described in Section 2, the transmitter pulse characteristics, power output, power stability, along with the antenna feed line loss were tested.

The pulse characteristics were tested at each of the four frequencies (30, 45, 60, and 90 megahertz) in terms of the pulse rise and fall time, pulse width, and the pulse repetition frequency. To evaluate these characteristics, the test was conducted by (1) optimizing the rise and fail time, and (2) measuring the pulse width, rise, and fall time under these

conditions with a peak power of 200 watts. The rise and fall times were measured over a range of approximately 10 dB whereas the pulse width was measured between the 3-dB points. The PRF was measured by using a scope and an internal calibrated sync. The results of these tests are presented in subsection 4.2.

The power output test was also defined for each of the four test frequencies. The power output was measured by using a Hewlett Packard 413B power meter. During each of the measurements, the pulse width at the 3-dB points was set at 1.0 microsecond.

To evaluate the power stability of the transmitter, a coupler was used to couple energy from the transmitter operating at 90 megahertz into the Hewlett Packard 413B power meter. The transmitter was terminated in a dummy load for this test, and the power meter indicator was recorded every 5 minutes over a one-hour period.

To evaluate the RF feed line systems (short-range system and long-range system), the losses in the transmitter and receiver feed lines between the antenna terminals and the feed points were measured for each of the two feed systems and at each of the four frequencies by using a Hewlett Packard 608 generator and the Hewlett Packard 413B power meter.

3.2.2 Receiver

The receiver design tested was described in Section 2; and in order to evaluate the performance of this design, a test program was defined to determine the noise figure, receiver noise, harmonic rejection, linearity, and compatibility with the present RAT SCAT phase measurement console.

The noise figure was measured at each of two frequencies (45 and 80 megahertz) by using each of the three IF amplifiers (.2-, .5-, 2-megahertz bandwidth). The measurements were made by using a PRD noise source as input to the RF preamplifier which can be calibrated to give the noise figure directly.

The receiver noise level was measured for each of the two frequencies 45 and 80 megahertz and for each of the three IF amplifiers. The technique used was that of connecting a calibrated signal source to the receiver and observing the level of the minimum discernible signal on a scope. If it is assumed that this level is 6 dB below the noise level of the receiver,

the receiver noise level can be determined. A Hewlett Packard 608 signal generator was used as the calibrated power source for these tests.

The harmonic rejection was to be measured at the two frequencies of 45 and 80 megahertz. The technique to be used was that of connecting the HP 608 signal generator to the receiver and measuring the amount of reduction at harmonic frequencies of 45 and 80 megahertz relative to the IF frequency (e.g. 30, 60, 65, and 95 megahertz). However, because of the wide band RF preamplifier becoming saturated, enough dynamic range could not be achieved to evaluate the amount of rejection afforded by the system.

The linearity of the measurement system was determined over a 50-dB dynamic range by recording the measured output change produced by adjusting a calibrated attenuation in the receiver line in 1-dB steps over a 50-dB dynamic range. To perform this test, a Weinschel Model 60A calibrated attenuator was used.

The phase measurement compatibility was determined by interconnecting the VHF IF signal which is translated to a 60-megahertz IF signal to the present RAT SCAT phase measurement console. By using this interconnection, phase data was obtained during the range qualification test program; this data was used to demonstrate the compatibility of the new system with the existing phase measurement system.

3.3 Antenna Tests

The basic antenna tests were performed at the Fort Worth Division antenna facility; and although the antenna design was the same for each of the ten sets of antennas, tests were conducted at each of the ten design frequencies. The basic test program was directed toward determining the free space VSWR of the antennas and the antenna patterns for each of the two principal polarization plans.

3.3.1 Antenna VSWR

The antenna free space VSWR was measured by pointing the antennas upward and adjusting the capacitors and the inductance bars of the antennas until a minimum VSWR was achieved at the design frequency (see Table 1 for the ten design frequencies).

The VSWR was monitored by using a Rohde and Schwarz Z diagraph for each of the twenty antennas in order to insure that no mechanical anomalies or electrical discontinuities were produced during construction.

3.3.2 Antenna Patterns

The antenna patterns for each of the twenty antennas were measured in each of the principal polarization planes at the design frequencies used to adjust for minimum VSWR (paragraph 3.3.1). The pattern measurements were made by using a Scientific Alanta pattern recorder system at a range of 300 feet. The standard reference used was a dipole in each case. Typical patterns are presented in Section 4, along with the values of the gain (relative to isotropic), and front-to-back ratio.

Table 1 ANTENNA DESIGNS

Design Frequency (MHz)	30	37.8	45.5	53.3	61.1	68.9	76.7	84.4	92.2	100
Number Constructed	2	2	2	2	2	2	2	2	2	2

3.4 Range Qualification Tests

The range qualification tests were designed to provide measured data with which to demonstrate the performance and/or acceptability of individual factors (e.g., field gradients, antenna isolation, cancellation stability, background levels, target support cross section) and the overall measurement capability. As in the case of the systems tests, the test frequency of 30, 45, 60, and 90 megahertz were chosen in order to obtain data which is representative of the 30- to 100-megahertz region and are such that computed data is available for the selection of the proper antenna heights and the comparison of the measured field probe data with calculated data. In addition, scale model data was available at two of the four selected frequencies (30 and 60 megahertz) for a comparison of the full scale data on the 20- and 40-foot cylindrival targets.

Similar data could also be obtained for comparison at the other two frequencies, if the scale models were measured at a frequency of 1980 megahertz. These model measurements were made at the RAT SCAT site during the program.

At the selected frequencies, both phase and amplitude data were obtained for the field probe measurements and the calibration and demonstration target measurements. The tests outlined were to be conducted at both horizontal and vertical polarizations and in most cases at both the short-range design (350 feet) and the long-range design (1500 feet). However, in the case of the short range, the isolation which was obtained when the hybrid range antenna system was used was not sufficient to allow cross section measurements. Also, since cross section and field probe data was obtained during the feasibility program by using a dual-antenna, short-range configuration, the effort originally scheduled for the short-range cross section measurements was spent on additional testing by use of the long-range system. Since with few exceptions the test procedures were the same at both range conditions, one test procedure is presented. For the steps during the test program at which the procedure is dependent on the range, a short range and long range procedure are noted. The tests in the range qualification category are grouped under the classifications (1) antenna isolation, (2) field probes, (3) calibration, (4) background and target support, and (5) cross section measurements.

3.4.1 Antenna Isolation

The antenna isolation tests were different for the cases of the short range and the long range. In the case of the short range, the isolation is determined primarily by the VSWR of the antenna when mounted on the antenna towers since the isolation will be that realized between the receiver and transmitter ports. In the case of the long-range, dual-antenna system, the isolation is determined by means of the antenna patterns, the antenna separation, and the relative heights of the antenna; the relative heights must be considered because of the ground plane effect.

However, two factors considered in defining the isolation test program were common to both systems. The first of these was the antenna height versus the field gradient in the target region of interest. In both series of tests, the antenna

heights were chosen such that acceptable field gradients would exist in the target region. The field gradients as a function of antenna height were available from the computer study in Reference 1. Field gradients were examined over a six-foot region in the vertical dimension (the horizontal gradients were known to be acceptable from the antenna patterns and $2D^2/\lambda$ criteria for phase) and considered acceptable if the one-way amplitude gradient was less than 1 dB and the one-way phase gradient was less than 180/8. The second factor was that it would be necessary to account for the amount of line loss as measured by the tests described in paragraph 3.2.1.

The short-range isolation tests were conducted at each of the four test frequencies by noting the signal level received after adjusting the antenna (tuning capacity and inductance bar for minimum return (minimum VSWR)). Then the antenna feed was terminated by means of a short, and the received signal level so obtained was recorded. The difference in dB between these two levels gave a direct measure of the isolation achievable at each of the frequencies tested without having to subtract analytically the line losses. Note that in each of these measurements, sufficient attenuation was placed between the transmitter and the hybrid box so that the short circuit did not noticeably alter the transmitter output. The measurements described above were made for both vertical and horizontal polarization.

In the long-range isolation tests, the antenna heights were again limited to a range in which the field gradients were acceptable. Within this range, the antenna heights were adjusted to achieve maximum isolation. This procedure was used for both the 130- and 160-foot antenna tower separations and at both vertical and horizontal polarization. In the case of vertical polarization when the 160-foot tower separation was employed, another technique was used in addition to the above tests. The front of the antennas were pointed toward each other by an amount between 0 and 15 degrees. This amount of rotation did not alter the gain in the target direction, but allowed more isolation to be achieved by optimizing the cancellation between the direct wave and ground reflected wave, and/or positioned the pattern nulls in a more optimum position.

To measure the isolation, the level of the received signal was recorded with the range gate positioned at the time of the first received pulse, and then the transmitter was fed into the receiver through a calibrated attenuator. The amount of attenuation which was necessary to make the latter signal level equal to the signal level with the antennas in the loop was then recorded as the amount of isolation, plus line losses.

The above test procedure was used to determine the amount of basic isolation afforded by the dual-antenna system. Another test was defined for use in determining the amount of operational isolation afforded by the antenna system and range gate. In the latter test, the range gate was to be placed just in front of the target support rather than at the time of the first received pulse. Measuring the isolation when the range gate was placed in this position would allow the amount of operational isolation to be determined. This procedure was used in the case of horizontal polarization, but in the case of vertical polarization, this test could not be performed with confidence because of the apparent ground target returns in the immediate vicinity of the pit range. An additional technique was used to evaluate the lower bound on the recovery range in which a single antenna was used to obtain the effect of RF ringing. In this test the transmitter was connected to an antenna through a coupler of which the other terminal was connected to the receiver. The antenna isolation then simulated with the appropriate attenuation in the receiver line and the recovery time noted. This test was conducted with the antenna in both vertical and horizontal polarization configurations and no differences were noted.

3.4.2 Field Probes

Vertical field probes of both the amplitude and phase were obtained by using either a dipole or sphere. The sphere was used when sufficient measurement sensitivity was available; and in the remaining cases, a dipole was used. The probes were obtained by connecting the probe target to a string pulley system which was connected to a servo system to drive the amplitude and phase recorders.

3.4.3 Calibration

The calibration procedure used was similar to that presently used at the RAT SCAT facility at the higher frequencies. In this procedure, a primary calibration device is used to calibrate a secondary standard located outside the range gate of the target region. The secondary standard is then used to maintain amplitude and phase calibration during a measurement period. The primary targets used to calibrate the secondary standard were dipoles and a 36-inch sphere. The secondary standard consisted of a hoop 5.5 feet in diameter mounted on a RAT SCAT mobile antenna tower and located approximately 500 feet behind and 15 degrees to the side of the target location. Prior to each measurement series, the amplitude and phase of the secondary standard were adjusted to the values originally determined by using the primary calibration target. After the measurement series was completed, the secondary standard level was again compared with the primary calibration device to ensure that such effects as frequency drift and changes in the radiation patterns over the secondary standard had not produced significant amplitude and/or phase changes in the secondary reference relative to the primary calibration device.

The above procedure was used in conjunction with the range-gated system and can be used even though the IF cancellation system is used to cancel the return at pit time. In the case of the short-range CW or long-pulse system, the use of the secondary standard technique is not feasible unless a stable target with sufficient return can be located at a considerable range from the antenna location. In this case, it was planned to use only a primary calibration device as used in the feasibility study and rely on system stability to maintain calibration through a measurement series.

However, the amount of isolation achievable by means of the short-range system prohibited measurements from being made; hence calibration was not accomplished in this case.

3.4.4 Background and Target Support

Because the background (with and without target support) cross section is usually the limiting factor in the minimum cross section capability of a range, tests were designed to

determine the background levels for the range configuration, pit, and target supports used in the demonstration program. The background level was divided into two types, one of which was referred to as the uncancelled (raw background) and the other, the cancelled background. In addition, it was planned to measure the cross section of the target support if the measurement sensitivity was sufficiently low and/or the target support was of sufficiently large cross section. However, the support cross section and/or background level and/or measurement sensitivity was such that in most cases the target support cross section could not be determined. The procedure to be used in measuring the target support was to determine the cross section level of the background at pit time without using IF cancellation. By use of this technique, the target support cross section (as modified by the field gradient) could be obtained directly if the uncancelled return at pit time was produced only by the column. However, scattered energy other than that produced by the target support was present during most of the measurements, and valid data on the specific cross section levels of the fiber glass columns were not obtained although upper bound information was obtained. The uncancelled and cancelled background levels were measured by recording these levels relative to the calibration target before and after cancellation. In addition receiver and system noise levels were recorded in terms of dBsm in order to determine the measurement limitations of the present system and the limitations caused by RFI.

3.4.5 Cross Section Measurements

Whereas the previous tests were defined to demonstrate and/or provide improvement information relative to the important individual factors associated with an operational cross section measurement system, the target measurement tests were defined to demonstrate the feasibility of adopting the system design developed under this program into an operational configuration. The test program consisted of measuring the cross section and phase of either a 40-foot or 20-foot (or both depending on the measurement sensitivity) cylinder. The cylinder was constructed by welding oil drums end-to-end, and such a cylinder being

mounted on the 65-foot fiberglass target support is illustrated in Figure 14. To obtain a reference with which the data obtained during the demonstration could be compared and evaluated relative to measurement accuracy, 1/44- and 1/22-scale models of the 40- and 20-foot cylinders, respectively, were constructed in the RAT SCAT shop and measured on the RAT SCAT range.

The 40-foot cylinder was measured at all four of the test frequencies and by using both vertical and horizontal polarizations. The 20-foot cylinder was measured at 60 and 90 megahertz at both polarizations and at 30 and 45 megahertz in the case of horizontal polarization.

SECTION 4

TEST PROGRAM RESULTS

4.1 General

The results of the demonstration test program delineated in Section 3 are presented in this section, and they are compared with theoretical or reference data. The results are presented under the two categories of system test results and range test results as outlined in Section 3. In cases where tests were conducted in addition to those outlined in Section 3, such tests are noted along with the reason for conducting the additional tests. Also, it will be noted that the range demonstration test program was conducted during a period of approximately four months. This span of time was longer than the time required to complete the tests but becuase of the unusually high precipitation occurring at the RAT SCAT Site during the test program, periods when tests could not be conducted were incurred. In addition, during the test program, it became apparent that because of the isotropic nature of the antennas, a larger area of land than originally anticipated needed to be leveled if the uncancelled background return in the case of vertical polarization was to be reduced. After the leveling operation, a few selected vertical polarization tests were conducted which also increased the overall time span of the test program.

4.2 System Test Results

The system test results reflect the performance of the VHF equipment, which was designed to operate both in a CW and pulse mode. Although an equipment design which meets both of these requirements would not be an optimum design if only one of the requirements were to be satisfied, the VHF equipment designed and constructed under this program appeared to be near optimum in either of the operational modes within the minimum pulse width constraint (.5 microsecond) of the design. However, since the results of the range test program indicated that a pulse system would be the most desirable operational configuration, the areas where improvements can be made to optimize the system for pulse operation are noted.

4.2.1 Transmitter Test Results

The transmitter test program was outlined in paragraph 3.2.1 in which the methods of determining the pulse characteristics power output, power stability, and the feed line losses were presented. The results from the tests in which these methods were used are presented in Figures 15 through 18.

In Figure 15, the pulse characteristics of the transmitter are indicated in terms of rise time, fall time, and pulse width at each of the four frequencies used in this test. In terms of these three characteristics, the design objective was .2 microsecond. These design objectives were met at each of the test frequencies and exceeded at 50 percent of the test frequencies. The design objective set for the pulse repetition frequency was 5000 $\pm$ 10 percent and this value was obtained by use of the chosen circuit design. If the present system is optimized for pulse operation, the rise and fall time, along with the pulse width, can be reduced to the .1- and .25-microsecond regions, respectively, by means of relatively minor changes.

In Figure 16, the power output of the transmitter as a function of frequency is indicated. Although the design objective of 200 watts was achieved, it is evident from the data in Figure 16 that a 5-dB loss in power between 30 and 90 megahertz is incurred by using the present design. As in the case of the pulse characteristics, the peak power output of the present system can be substantially increased (especially at the higher frequencies) with relatively minor changes by optimizing the system for pulse operation.

In Figure 17, the stability of the transmitter output during operations at 90 megahertz is indicated. If it is assumed that the data in Figure 17 is representative, the stability of the system is substantially better than the design objective of $\pm$.25 dB over the period of time indicated in the figure.

In Figure 18, the line losses measured for the two feed configurations are noted as a function of frequency. Also indicated in Figure 18 are the theoretical losses for the type and length of lines used, and a comparison between theory and experiment indicates that no unexpected loss factors were encountered because of connectors. To obtain the line loss data for the single antenna system -3 dB was subtracted from the measurement data to account for the loss in the dummy load.

Note that the receiver feed line losses are also included in Figure 18 and the sum of the transmitter and receiver losses in the case of the dual antenna system should be subtracted from the isolation test data in order to obtain the amount of isolation. However, in the final long-range test configuration, shorter lines were used than those on which the data in Figure 18 were derived. The losses in these shorter lines were used to obtain the isolation data subsequently presented in Figure 33.

4.2.2 Receiver Test Results

The receiver test program was defined in paragraph 3.2.2 in which the methods of determining the noise figure, noise level, harmonic rejection, and linearity characteristics of the receiver were discussed. The results of tests based on the use of these methods are presented in Figures 19 and 20.

In Figure 19, the results from the receiver noise figure and noise level tests are plotted as a function of bandwidth. In the case of the noise figure, the design objective (8 dB) was exceeded at both of the test frequencies. In the case of the receiver noise level, the design objectives were -119, -115, and -109 dBm at the bandwidths of .2, .5, and 2 megahertz, respectively. Inspection of the data indicates that the design objective was met in half of the tests conducted.

The harmonic rejection could not be measured as discussed in paragraph 3.2.3 because of saturation problems with the wide band RF preamplifier. However, since the rejected level was below noise at both test frequencies of 45 and 80 megahertz when the RF amplifier saturated (saturation occurred at -33 dBm), it was concluded that the harmonic rejection capability was sufficient in an operation sense although the design objective value of 100 dB could not be verified.

In Figure 20, receiver linearity is plotted over a 50-dB dynamic range. The test was conducted at a frequency of 30 megahertz, and the maximum deviation over this range was less than .5 dB. This value is well within the design objective of 1 dB.

4.2.3 Antenna Test Results

The antenna test program was delineated in paragraph 3.2.3 in which the methods of determining the free space VSWR, antenna patterns, and operational VSWR were presented. Results from these tests are presented in Figures 21 through 30.

In Figures 21 through 28, the antenna patterns for the antenna designs used at each of the four test frequencies are presented. Both the vertical and horizontal plane patterns are presented, as well as both the transmit and receive antenna patterns. Upon examination of the patterns, it can be seen that disregarding minor anomalies, the patterns are the same, except in the region of 45 megahertz where a noticeable reduction in the front-to-back ratio exists. In Figure 29, the gain and front-to-back ratio is plotted as a function of frequency for all ten of the antenna designs constructed (see Table 1). By inspection of the data in Figure 29, it can be seen that the data in Figures 21 through 29 are typical of the antenna patterns. It should be noted that the gains of the antennas presented in the Figures 21 through 28 are expressed relative to a dipole (2 dB) whereas the gains in Figure 29 are relative to an isotropic radiator. Except at a few of the frequencies, the antenna gains were within 2 dB of the design objective (10 dB). Also, it should be noted that the beamwidths of the antennas, as well as the relatively low front-to-back ratios, indicate the need for having a relatively large smooth area of land within which to operate a range-gated system in the VHF region.

In Figure 30, the results from the VSWR tests are presented for both the free space tests conducted at the Fort Worth Division and the operational tests conducted at RAT SCAT. Upon inspection of the data, it is apparent that the free space VSWR is significantly lower than that which could be achieved by using the antennas mounted on the antenna towers. Although operational VSWR is still relatively low (and within the design objective of 2 when the amount of reflected versus ratiated power is considered), the VSWR is much too high to allow a sufficient amount of isolation to be achieved by using a hybrid system (see Figure 7). In order to see if substantial improvements (typically, reductions of 1.3

down to values of 1.01 are needed to make the hybrid system feasible) could be achieved by using fiberglass towers instead of steel towers, an antenna was mounted on the fiberglass boom of a RAT SCAT cherry picker and tested at a height of forty feed. Although some improvement was noted, it was not of the order indicated above; and it was concluded that the vicinity of the ground, as well as the towers, would limit the achievable VSWR's to a nonoperational level relative to a hybrid system.

4.3 Range Test Results

In this section, the results from the range qualification test program are presented. The test program was delineated in subsection 3.3 in terms of the tests conducted to evaluate performance in the areas of antenna isolation, field gradients, calibration, background and target supports, and cross section measurements. In addition to the tests discussed in subsection 3.3, some additional tests were conducted in connection with the unanticipated background problems encountered in the case of vertical polarization. These additional tests were conducted to obtain information with which to optimize the equipment, the range length, and possibly the range topological condition and pit designs, in order that a fully operational measurement capability can be implemented at the RAT SCAT Site. These additional tests were conducted primarily in the areas of system recovery time and apparent surface field scattering. In addition, a limited analysis was conducted to demonstrate the applicability of using vector field subtraction in the 30- to 250-megahertz region as a standard technique for reducing the background levels when necessary.

4.3.1 Antenna Isolation

The antenna isolation tests were described in paragraph 3.4.1 in the case of the single-antenna hybrid system and the dual-antenna system. Presented in Figures 31 through 34 are the data obtained from these tests.

In Figure 31, the isolation data from the single-antenna hybrid system are presented, along with theoretical data computed from the operational VSWR test data presented in

Figure 30. The discrepancies between the measured isolation data and that computed can be accounted for, at least partially, by means of the facts that the antenna heights at which the operational VSWR were measured were slightly different from those used in the isolation tests and that the transmitter VSWR is much larger than the VSWR of the Rhlode and Schwarz Z diagraph (VSWR meter). However, even without considering these differences, the measured and computed data are compatible.

In Figure 32, the cancellation test results are presented for the cases considered to be operational environmental conditions and limited environmental conditions. The operational environmental conditions refer to conditions in which the wind is less than or equal to 15 miles per hour and the amount of cancellation indicated in Figure 32 can be maintained for a period of 30 minutes or greater. The limited environmental conditions refer to wind conditions less than approximately 5 miles per hour, and the cancellation levels indicated in the figure can be maintained for periods of 15 minutes or greater. The cancellation levels presented in Figure 32 were obtained by using both the hybrid system and the dual-antenna system. This test was conducted to ascertain if one of the two systems afforded an advantage in terms of cancellation stability. As suggested above, there were no significant differences noted between the two systems.

In Figure 33, the data obtained from the dual-antenna isolation tests are presented, along with computed data. The measured data was obtained after adjusting the antenna heights in the vicinity of 48 feet for maximum isolation. In all cases, the antennas were placed within 5 feet of 48 feet for obtaining the measured data presented in Figure 33. Figure 33 also contains measured isolation data obtained in the case of vertical polarization by pointing the front of antennas inward. The angles involved in these tests were less than 20 degrees in all cases; hence an insignificant reduction in gain in the target direction occurred. However, due to the antenna pattern in the vertical polarization case (see Figures 22 through 28) and/or by optimizing the phasing between the direct and ground reflected waves, a significant increase in isolation was achieved.

The computed data was obtained by using the average of measured antenna patterns over a 25-degree sector centered about broadside, the computed ground plane field intensity, and the standard radiation equation as given in Reference 3. By comparing the measured and computed data, it can be seen that the measured datais relatively close to the values expected on the basis of the considerations used in the theory.

Figure 34 contains system isolation and recovery range data which was obtained by the methods described in paragraph 3.4.1. Note that the recovery range in the case of vertical polarization is indicated within a band whereas the recovery range for horizontal polarization is not. The reason for the uncertainty in the vertical polarization case was due to the ground returns masking of the range at which the system completely recovered with both antennas in the loop. This problem is discussed in more detail in paragraph 4.3.4. Note that the amount of attenuation used in the transmitter and/or receiver to obtain recovery at the indicated range is indicated at each of the frequencies and for each polarization. The lower bound on the recovery range is that determined by the single-antenna test and is indicated by the dashed line in Figure 34. The electronic system recovery range is also indicated in Figure 34 for the case in which the antenna isolation at each of the test frequencies was simulated with the amount of attenuation indicated in Figure 33 and the actual line lengths used in conjunction with the dual-antenna system were used to connect the transmitter to the receiver. The difference between the electronic system recovery range and the recovery range with both antennas in the loop was caused by RF ringing and/or ground reflections.

4.3.2 Field Probes

The field probe data was measured at each of the four test frequencies by the method described in paragraph 3.4.2. Presented in Figures 35 through 42 are the results of these tests, along with the theoretical field probe data for each of these cases. The measured data presented in Figures 35 through 42 was obtained from the recorded analog plots obtained in the manner indicated in paragraph 3.4.2. A comparison between the measured data and that computed will

show that the radiation model used to obtain the computed data is a valid model in terms of phase, as well as amplitude. The amplitude correlation was demonstrated during the feasibility study (Reference 1).

4.3.3 Calibration

The primary and secondary calibration targets used in the test program were described in paragraph 3.4.3, along with the procedure used to validate the stability and accuracy of calibration procedure. The accuracy of the calibration procedure used is indicated in Table 2, in which the amplitude error between full scale measurements and scale model measurements is interpreted as calibration error. The data presented is for the cases in which the calibration target was at least 15 dB above the background. A demonstration of the accuracy in the procedure used to calibrate phase is presented in paragraph 4.3.4. There the vector field subtraction technique is demonstrated using phase information obtained in the measurement program. Although the data in Table 2 indicates that the calibration targets and procedures can be used as an operational technique, the position of the secondary standard used in the demonstration was such that forward scatter from the target could cause an error of up to 1 dB (possibly inducing some of the error in the data of Table 2). This fact is demonstrated by the data in Figure 43 and is a plot of the secondary amplitude variation with target rotation when operating at 30 megahertz in horizontal polarization. The data in Figure 43

Table 2 CALIBRATION DATA

	Frequency (MHz)			
	30	45	60	90
Dipole Error (dB)	1.0 HP	1.0 HP	0.5 VP	0.7 HP
Sphere Error (dB)		1.5 VP	0.5 HP	0.5 VP

is typical of forward scattering effects on amplitude observed at each of the test frequencies. The effects on the phase of the secondary standard were less noticeable, being less than 5 degrees in all cases although if present on an operational system, even this magnitude error would limit any vector field subtraction techniques.

4.3.4 Background and Target Supports

The basic tests conducted to determine the background and target support levels as a function of polarization and frequency were described in paragraph 3.4.4. In addition to the tests described in paragraph 3.4.4, several additional tests and investigations were conducted in connection with the background and target support levels in the case of vertical polarization. These additional tests were conducted because of the unexpectedly large return occurring in the vicinity of pit time. These tests are described in connection with the data presented in Figures 53 through 55. This discussion follows a general discussion of the background and target support test results.

Figure 44 contains background data obtained at each of the four test frequencies in the case of vertical and horizontal polarization. The data presented in Figure 44 is the average cross section determined by rotating the target support through 360 degrees. As indicated in Figure 44, background levels were obtained in the case of vertical polarization under two basicly different surface conditions, as well as with and without the IF cancellation. Also noted in Figure 44 are the receiver and system noise levels in terms of dBsm.

Background plots of cross section and phase are presented in Figures 45 through 52 in which IF cancellation was not used. The horizontal polarization data, as well as the vertical polarization data noted as being obtained before leveling was obtained during the early portion of the test program before the range was completely leveled. During this period, only a path approximately 15 degrees wide at the large range had been cleared. The data obtained after leveling the complete

range gate region of 2000 feet (see Figure 1) is noted as occurring after leveling. By inspection of the data in Figure 44 it can be seen that the raw background (uncancelled) level was reduced 5 to 8 dB after the leveling operation and the cancelled level was reduced 15 to 20 dB. The greater decrease in the cancelled background over that of the uncancelled background was attributed to the fact that a better match between the shape of the cancellation wave form and the background wave form was achieved after the leveling operation.

Although the background level was noticeably reduced after the leveling operation, a significant return near pit time was still present at both of the test frequencies (45 and 60 megahertz) used in the investigation. In Figures 53, 54, and 55, the nature of the return which is near pit time is illustrated in the case of 45 megahertz (this was the most severe of the two cases), under two different antenna terminating conditions, and with and without the target support column. In Figure 53, the transmitter was connected to the antenna by means of 100 feet of cable, and 3 dB was inserted into the line to enhance recovery. Oscillographs (a), (b), (c), and (d) were obtained with 43, 33, 23, and 13 dB, respectively, in the receiver line. In all cases, the pit time of 3 microseconds (1500 feet) corresponds to the horizontal center line, and the scale is 500 feet per centimeter. The top trace is the range gate (.1 microsecond wide) and is located at pit time in Figure 53. The blanking switch was turned off at 800 feet during all of the tests depicted in the oscillographs of Figure 53. Note that a significant return is obtained at ranges of 2000 feet and 2600 feet. At the 2000 foot range, a two-foot-high dike was observed approximately 20 degrees to the left of the pit (see Figure 1). The dike is part of a ditch used to drain water from the RAT SCAT operational area. At the 2600 foot range, the shelter for pit number 3 was located 80 degrees to the left of the pit and is a metal building approximately 30 x 30 x 30 feet in size. These two returns were observed at all of the four frequencies tested in the case of vertical polarization. In Figure 53a, the return at pit time (slightly beyond) was 7 dB higher than the system noise which, as indicated in Figure 44, corresponded to -10 dBsm (measured at pit time). Note that as attenuation was removed from the receiver line, the

pattern did not change, only the amplitude increased by the amount of attenuation removed. This result indicates that the return was not caused by RF ringing in the receiver line. To demonstrate that the transmitter line had little effect on the returns indicated in Figure 53, a 300-foot section of line was added to the 100-foot transmitter feed line, along with the 13 dB of attenuation (additional attenuation was necessary to remove the noticeable ringing effects before pit time) to achieve the same range of total attenuation used in Figure 53. Data obtained from this test is presented in Figure 54 in which oscillographs (a), (b), and (d) were obtained with 41, 31 and 21 dB, respectively, of total attenuation in the system. The only difference between the conditions under which Figures 54b and 54c were obtained were that the local oscillator blanking was removed at 600 feet in Figure 54c versus 800 feet in Figure 54b whereas it was positioned 200 feet behind the pit range in Figure 54b. The effect on the level recorded at pit time of removing the blanking at 600 feet rather than 800 feet was not noticeable as it would be if the IF system was not fully recovered near pit time. Further evidence that no IF recovery problems were associated with the returns observed near pit time is presented in Figure 55 in which the return is recorded with and without blanking. By comparing the returns indicated in Figure 54 with those in Figure 53, it can be seen that the same returns are observed under both sets of conditions. After obtaining the data presented in Figures 53 and 54 in which the 30-foot column was present and the cover plates which were covering the pit cavity were covered with soil approximately 2 inches thick, the column was removed; and the entire pit cover and rotator was covered with approximately 2 inches of soil. The data obtained in this series of tests is shown in Figure 55. In Figures 55a and 55b oscillographs of the near pit return, without the column and the pit cover conditions described above, are presented for the cases of local oscillator blanking and no local oscillator blanking. Figure 55c contains the reference data obtained with the column in place and no blanking. Although the amplitude levels are not indicated on the oscillographs, the observed levels with and without the column were the same. This last test was conducted to ensure that the column was not being observed even though previous tests had indicated this to be the case. Also, the results

from this test indicate that additional investigations should be conducted relative to the existing terrain conditions and pit location before choosing the optimum pit location for an operational range. For example, the data in Figures 53, 54, and 55 are typical of the background return in vertical polarization observed at each of the four test frequencies in that at 1200 and 1750 feet a relatively low return (10 to 15 dB), compared to that at pit time, was observed in all cases. Hence if a pit was located in these regions, uncancelled background levels of -20 dBsm could be obtained in the case of vertical as well as horizontal polarization. This recommendation is discussed further in paragraph 5.3.2.

In addition to the IF cancellation technique used to reduce the background, use of a technique called vector field subtraction which was demonstrated at RAT SCAT in 1964 (Reference 4) is certainly feasible in the VHF region, and the technique can be used to overcome the problem of phase center and amplitude variations caused by target support rotation. The results of such variations are indicated in Figure 56 in which the cancelled background is plotted for the case of horizontal polarization at 92.2 megahertz. By use of vector field subtraction, (see paragraph 4.3.5) the effects of target support cross section variations can be removed by using the present RAT SCAT computer and vector field subtraction program.

4.3.5 Cross Section Measurements

The cross section measurement program was described in paragraph 3.4.5 in which the types of targets and measurement frequencies used in the demonstration program were delineated. The results of this measurement program are presented in Figures 57 through 83 and include data obtained at each of the four measurement frequencies, data obtained by using both vertical and horizontal polarizations, data obtained by using both the 25 and 65-foot target supports, data on both phase and amplitude, and scale model data obtained at the RAT SCAT facility by using a frequency of 1980 megahertz. The full scale data in Figures 57 through 72 was obtained before the terrain leveling operation whereas the data in Figures 81 and 82 was obtained after the leveling was completed.

The data in Figure 83 is presented to demonstrate the feasibility of using vector field subtraction as a means of reducing the background. The scaled model data presented is only for the cases of 45.5 and 92.2 megahertz full scale data. Scale model data (amplitude only) for the 30- and 61.1-megahertz full scale measurements are reported in Reference 1.

By comparing the data in Figures 57 through 72 with the appropriate scale model data in Figures 73 through 80 and the appropriate scale model data in Figures 108 through 111 of Reference 1, it can be seen that the data obtained in the case of horizontal polarization is quite valid (even in the end on region) whereas, except at 92.2 megahertz, the data obtained in vertical polarization is significantly degraded because of the high background levels. Vertical polarization data comparable to that obtained at 92.2 megahertz was also obtained at 61.1 megahertz after the leveling operation and is presented in Figure 81. The vertical polarization background levels obtained at 45.5 megahertz (indicated in Figure 44) were also sufficiently low after the leveling operation to permit valid cross section measurements to be obtained on the 40-foot cylinder barrels. However, it appears that because of the large level and position of the cancellation pulse that was used during the target measurements (the large level was required to obtain the required shape to cancel the trailing edge of the return just before the pit time indicated in the oscillographs of Figures 53, 54, and 55), the IF was not fully recovered at the position of the range gate (the range gate was positioned over the maximum return at broadside which was slightly different from the position at which the background was cancelled; normally a slight change in the position has little effect on the measurements except to shift the levels). The effect upon the measurement system appeared to be that of producing a nonlinearity. This type problem could be prevented if the IF cancellation pulse circuit was modified to obtain a wider range of wave forms than that presently available and/or vector field subtraction was used. Additional evidence that the data in Figure 82 is invalid is obtained by reducing the background by vector field subtraction as indicated in Figure 83. The data in Figure 83 was obtained by subtracting the background

data presented in Figures 47 and 48 from the measured data presented in Figures 63 and 64. Computations were made in the region of the peaks and nulls indicated by the model measurements, and the resultant data is indicated in Figure 83 along with the model data obtained from Figure 73. Comparison of the data indicates that the effective background levels produced by the subtraction process was -20 dBsm (or lower), and also that the data presented in Figure 82 was invalid.

In summary, the data obtained under low background conditions indicates that the reduced bistatic and tilt angles afforded by the long range configurations allows valid cross section data to be obtained in the 30- to 100-megahertz region. Also, the background test results in the case of vertical polarization indicate that additional tests need be conducted to determine the optimum pit location(s). This problem is discussed further in Section 5.

SECTION 5

SUMMARY AND RECOMMENDATIONS

5.1 General

A summary of the VHF program investigation is presented in this section, and includes a brief summary of the feasibility investigation reported in Reference 1 along with a summary of the demonstration program results and recommendations relative to an operational VHF facility at RAT SCAT. In general, results from the VHF demonstration programs and feasibility studies (Reference 1) demonstrate that valid radar cross section measurements can be made in the 30 to 100 megahertz frequency region at RAT SCAT by using either a short-range dual-antenna system RF cancellation technique or a long-range pulsed system technique in which an IF cancellation and/or vector field subtraction can be used. Also, results obtained during the program demonstrate that a short-range single-antenna hybrid system is not a feasible technique to be employed on an outdoor range due to limitations in the amount of isolation and operational cancellation levels which can be obtained.

It is recommended that the electronic system developed during this program be extended to cover the 100- to 250-megahertz region and that the system be optimized for pulsed operation in the 30- to 250-megahertz region. The recommendation to extend the frequency range of the VHF electronic system to cover the present RAT SCAT band 1 frequencies is based primarily on the results obtained during the feasibility study which indicate that (1) a relative large smooth region and a carefully designed pit rotator system are required to allow for system recovery and reduce the background to operational levels, especially in the case of vertical polarization, and (2) IF cancellation and/or vector field subtraction are operationally feasible techniques which can be used to reduce the background levels currently achievable with the band 1 system.

As implied above, it is recommended that the longer range pulsed technique be used at RAT SCAT since the necessary range is available and this approach has the advantages that (1) there are practically no target size limitations, as in the case of the short range approach; (2) the necessary cancellation levels ($\approx$20 dB) required to achieve relatively low backgrounds are not significantly affected by normal RAT SCAT environmental conditions over long periods of time (several hours); (3) the same antenna heights can be used for both polarizations (consequently, it is feasible to obtain scattering matrix information with which to generate cross section data for polarizations other than horizontal and vertical); and (4) the operational procedures, such as maintaining calibration, would be very similar to those presently used at RAT SCAT when operating at the higher frequencies.

Subsection 5.2 contains a summary of the results of the equipment performance tests and range design tests, obtained during the demonstration program. Based on the results presented in 5.2 and those presented in Reference 1, recommendations are given in Subsection 5.3 relative to implementing an operational VHF system at RAT SCAT in which a major portion of the equipment constructed during the demonstration program would be used.

5.2 Summary

A feasibility investigation was conducted during the first phase of a two-phase program in which tests were conducted at RAT SCAT. A Fort Worth Division electronic system was used to investigate the basic feasibility of obtaining valid radar cross section measurements. Analytical studies validated by measurements were conducted to (1) determine the RAT SCAT soil electrical properties under the climatic conditions expected at RAT SCAT (moisture and temperature), (2) determine the RF fields to be expected under the various soil conditions by using realizable ranges, antenna heights, and target heights, (3) demonstrate the feasibility of obtaining valid cross section data at the RAT SCAT facility, and (4) derive equipment designs and range design(s) which could be implemented and evaluated during the second phase of the program to demonstrate that an operational system could be implemented at RAT SCAT. The results obtained from the first phase of the program indicate the

feasibility of making valid cross section measurements, and they were used to derive equipment and range designs for demonstrations at RAT SCAT.

The results from the feasibility study (Reference 1) indicated that a coherent electronic system could be used to make valid measurements by using a short-range, dual-antenna system and employing an RF cancellation network to reduce the feed through and background to operational levels. However, the results also indicated that if such an approach were used, the target sizes at which valid cross section data could be expected would be restricted to size below those commensurate with a cylinder 5 feet in diameter and 20 feet in length; this size restriction is required to reduce errors caused by target ground coupling, tilt angle and bistatic angle. Hence a coherent electronic system and antenna system was constructed which could be operated in the manner outlined above. However, in order to remove the undesirable effects caused by the rather large bistatic angle involved with a short-range, dual-antenna configuration, a single-antenna hybrid system was constructed, for evaluation during the demonstration phase of the program. If such a system would allow a similar amount of isolation plus cancellation to be achieved as in the case of the dual-antenna system, background levels in the -20 to -40 dBsm range could be contained in the 30- to 180-megahertz region for vertical and horizontal polarization.

The results from the feasibility study also indicated that it was technically feasible to make valid measurements at RAT SCAT by using a long-range, dual-antenna system in which antenna separation and range gating could be used to obtain the required isolation. Although this technique was not validated during the feasibility investigation (equipment was not available), the indicated superior measurement capability, in terms of target size, RF field gradients, and operational convenience for the same measurement sensitivity of the short range, was such that this technique was also chosen for evaluation during the demonstration program. Hence, a coherent electronic system was design and constructed to operate in both a pulsed and CW mode; two antenna configurations were implemented; and two range lengths were selected at which target support pits were constructed.

A test program was defined in which the techniques to be used in evaluating the electronic system, antenna systems, and range designs were delineated. The test program, along with a description of the electronic and antenna designs, was discussed in Section 3. The detailed results obtained from the test program were presented in Section 4 and are summarized in the subsequent paragraphs.

5.2.1 Demonstration Equipment

The demonstration equipment designed and implemented during the second phase of the program consisted of (1) a transmitter capable of coherent transmission operating in both a pulsed and CW mode over the frequency range of 30 to 100 megahertz; (2) a low noise figure receiver compatible with the requirements for signal cancellation (operating CW and pulsed) and compatible with utilization of the existing RAT SCAT cross section and phase measurement consoles; (3) a set of antennas, hybrids, and supports allowing operation at any frequency between 30 and 100 megahertz with antenna heights up to 60 feet in both the single-antenna hybrid configuration and dual-antenna configuration; and (4) a two-pit design capable of housing a rotator with the capability of supporting and controlling a 36-inch diameter target support up to 65 feet in length and loads up to 4000 pounds.

A description of the transmitter test program was given in paragraph 3.2.1, and the test results were discussed in paragraph 4.2.1. The results demonstrated that the transmitter is capable of (1) transmitting 200 watts power in the 30- to 100-megahertz region operating at CW and pulse widths down to .5 microsecond, (2) operating over at least a period of one hour with amplitude variations no greater than .1 dB, (3) producing pulses with rise and fall times no greater than .2 microsecond at a pulse repetition frequency of 5000 ± 10 percent. In addition, tests were conducted, and it was demonstrated that the connecting RF lines between the antenna hybrid and/or dual antennas and equipment were free of losses other than those produced by the type cable used and length of line employed.

A description of the receiver test program was given in paragraph 3.2.2, and the test results were discussed in paragraph 4.2.2. The results demonstrated that the receiver is capable of (1) operating with a noise figure below 6 dB, (2) operating with any of three 15 megahertz amplifiers which provide bandwidths of .2, .5, and 2 megahertz and noise levels in the regions of -115, -113, and -109 dB, respectively, (3) providing a delayed coherent IF signal whose amplitude and phase can be controlled and used to cancel unwanted returns within the range gate, and (4) providing the frequency translated IF signals to operate the existing cross section and phase measurement consoles which operate at 60 megahertz. In addition, an RF cancellation console was provided and operated satisfactorily to cancel the RF feed through and background signal when demonstrating the single antenna hybrid technique.

A description of the antenna test program was given in subsection 3.3, and the test results were presented in paragraphs 4.2.3 and 4.3.1. The results demonstrated that the ten sets of two five-element yagis, hybrid and two 60-foot antenna towers would (1) allow gains in the 7 to 10 dB region to be achieved with front-to-back ratios in the range of 10 to 15 dB, (2) allow VSWR's in the range of 1.005 to 1.05 to be achieved in free space and 1.2 to 1.6 to be achieved when mounted on the 60 foot towers at RAT SCAT, (3) allow only 15 to 20 dB of isolation to be achieved when the single antenna hybrid system is employed, (4) allow 40 to 55 dB of RF cancellation to be maintained over periods of 30 minutes under normal RAT SCAT environmental conditions using either the hybrid system or dual antenna system, (5) allow 55 to 70 dB of RF cancellation to be achieved under limited environmental conditions, and (6) allow isolation levels in the range of 55 to 80 dB to be achieved using the dual antenna configuration with an antenna tower separation of 160 feet.

5.2.2 Demonstration Range Designs

The range designs evaluated during the demonstration program were described in subsection 2.3 and the evaluation of these ranges was conducted using the demonstration equipment whose performance was summarized in the previous paragraphs.

The two range designs evaluated were a short range in which a rotator pit was located 350 feet from the antennas and a long range in which a pit was located 1500 feet from the antennas. The location of these pits relative to the antennas and present RAT SCAT ranges is shown in Figure 1. This location was chosen because it afforded a 4000 feet diameter region free from structures and traffic which would disallow a range gated operation and endanger the operational feasibility of a cancellation system. During the major portion of the demonstration program, only a portion of the terrain in the operating region had been graded to remove the sand dunes. However, during the program it was demonstrated that significant scattered energy was being returned from these relatively large terrain anomalies in the case of vertical polarization (especially under conditions of high moisture content) and subsequently the entire region depicted in Figure 1 was graded. After the grading operation a limited amount of testing was conducted to evaluate the improvement afforded in terms of vertical polarization background.

The range qualification test program was presented in subsection 3.4 and the results obtained from the tests were presented in subsection 4.3. The factors considered during the range qualification program were (1) the RF field patterns in the vicinity of the target, (2) calibration targets and procedures, (3) background and target support cross section, and (4) the ability to obtain valid radar cross section data using the equipment and range geometries developed during the VHF program. Summaries of the results obtained in connection with each of these four factors are presented in the following paragraphs.

A description of the RF field probe test program was given in paragraph 3.4.2 and test results discussed in paragraph 4.3.2. The results demonstrate that (1) the ground plane model computer program can be used to compute valid amplitude gradients in the vicinity of 60 to 70 feet are no greater than 1 dB and 180/8 degrees respectively over a six-foot region; (3) when using the 1500 foot range the field gradients indicated in (2) can be achieved with a fixed antenna height at all frequencies in the 30- to 100-megahertz region and for both

vertical and horizontal polarization; and (4) in the case of vertical polarization above 60 megahertz, the field intensity is noticeably influenced by soil moisture conditions above the normal 15 percent moisture content at RAT SCAT.

A description of the calibration test program was given in paragraph 3.4.3 and the results from the test program discussed in paragraph 4.3.3. The results demonstrated that (1) the calibration targets of spheres and dipoles can be mounted on the fiberglass columns and used to calibrate the system to allow measurement accuracies within 1 dB (see Table 2; (2) the range gated system can be operated using a secondary standard to maintain amplitude and phase calibration; and (3) the position of the secondary standard must be chosen to avoid errors produced by bistatic scattering between the secondary standard and target.

A description of the background and target support test program was given in paragraph 3.4.4 and the test results discussed in paragraph 4.3.4. The test results demonstrated that (1) the isolation afforded by a single antenna hybrid system in the 30- to 100-megahertz region is insufficient to allow background levels considered to be operational (below -20 dBsm) when operating at range lengths greater than 150 feet, (2) sufficient isolation can be achieved with a dual antenna system to allow operational background levels to be achieved using the RF cancellation network and operating at the short range of 350 feet, (3) using the range gated technique, operational background levels can be obtained at 1500 feet without using IF cancellation, (4) using the range gated system, operational background levels can be obtained in the case of vertical polarization using IF cancellation, (5) RFI was insignificant but noise was 4 to 10 dB greater than receiver noise in the 45- to 30-megahertz region, (6) a significant return (nominally 20 dB above system noise) was present near pit time in the case of vertical polarization at all test frequencies, (7) operational background levels could be achieved near pit time ($\pm$500 feet) in the case of vertical polarization, (8) the system recovery range was within 1500 feet at all frequencies in the case of horizontal polarization and possibly in the case of vertical polarization although apparent ground and/or pit return disallowed positive

determination of the recovery range in this case, (9) the target support cross section was only identifiable at the high test frequency of 92.2 megahertz and the level of identification indicates that the target support cross section is sufficiently low as to allow operational background levels, (10) the phase and amplitude stability of the background is such that vector field subtraction is a feasible operational technique which can be employed to obtain relatively low background levels, and (11) it was necessary to employ the rotator pit covers to achieve the uncancelled background levels presented in Figure 44.

A description of the cross section measurement program was given in paragraph 3.4.5 and the test results discussed in paragraph 4.3.5. The test results demonstrated that (1) valid cross section measurements could be made with the 1500 foot range and dual antenna design, using the electronic equipment developed during the program; (2) valid phase data could be obtained using the system described in (1); (3) valid measurements could not be obtained using the single antenna hybrid system because of the high background levels; and (4) target handling equipment in excess of that presently available at RAT SCAT is required for the above forty feet target support columns.

5.3 Recommendataions

In the summary of the feasibility and demonstration program results, it was generally noted that it was possible to make valid cross section measurements using either the short range dual-antenna RF cancellation technique or the long range dual-antenna range gating technique. However, it should be noted that the long range technique offers certain advantages over the short range technique and conversely. In particular, the long range technique has the advantages that (1) the same antenna heights can be used for both polarizations; (2) uniform field gradients can be obtained over a larger region (60 foot long targets versus 20 foot long targets); (3) bistatic and tilt angles are approximately one fifth and two fifths of those produced at the short range; (4) calibration techniques

are the same as those presently used at RAT SCAT; (5) measurement interference by traffic is reduced to the range gate region rather than the entire vicinity as in the CW case; and (6) measurements can be conducted under environmental conditions commensurate with those presently dictating operation at the higher frequencies. The disadvantages are primarily that (1) when using the target heights above 40 feet, additional target handling equipment is necessary; and (2) a larger region need be maintained in terms of terrain conditions. Considering that these advantages and disadvantages prevail for approximately the same background levels (-20 to -40 dBsm) and the present equipment developed during the VHF program, it is recommended that the long range technique be used in the event that an operational system is implemented at the RAT SCAT facility. By implementing only the range gated technique the electronic system and the range designs can both be optimized for a single technique rather than compromised, which would be the case for a dual technique. In general, the modifications necessary to optimize the present electronic equipment for long range operation are minor in the case of 30- to 100-megahertz. Also, the results from the background tests indicate that the range length of 1500 feet is near optimum in the 30- to 100-megahertz region and the optimum range for pit locations could be determined using the optimized system under a relatively small test program directed at this objective. It is also recommended that the present coherent electronic system be extended in frequency coverage to include the RAT SCAT band 1 frequencies (100- to 250-megahertz). This extension would provide a coherent system, located in a vicinity designed specifically for the lower frequencies in which the surface field in the case of vertical polarization required special terrain and pit design considerations, with which to improve the background levels presently achievable with the band 1 system (by more optimum range conditions and by the use of cancellation techniques). In addition, this inclusion of the band 1 frequencies into the VHF region would allow the present RAT SCAT 30 foot antennas (two) to be used to improve the isolation and sensitivity in the 60- to 100-megahertz region relative to those achieved with the demonstration antennas.

In connection with the above recommendations, consideration should also be given to additional items which would be required to provide an operational VHF capability at the RAT SCAT site. Although such items (e.g. power, rotators, etc.) are not primary considerations in a feasibility study such as the one being reported, they become major items when considering the implementation of an operational system designed to withstand environmental conditions. The recommendations indicated above are presented below in terms of equipment design, range design, and operational considerations.

5.3.1 Equipment Design

Based on the results from the feasibility and demonstration programs and the considerations discussed above, recommendations are presented relative to an operational equipment design involving the electronic system (transmitter, receiver) and antenna system for operation in the 30- to 250-megahertz region.

To provide operational capability, it is recommended that the transmitter developed under the current program be optimized for pulse operation by (1) reducing the pulse width to the .25 microsecond region while maintaining a peak power output of at least 200 watts, and (2) extending the frequency coverage to 250 megahertz.

To provide operational capability it is recommended that the receiver developed under the current program be optimized for pulsed operation employing IF cancellation by (1) providing an additional amplifier with a bandwidth of 4 megahertz and optimized in terms of recovery time; (2) providing a low noise RF amplifier to cover the 100- to 250-megahertz range; and (3) improving the pulse shaping characteristics of the IF cancellation network.

To provide operational capability it is recommended that antenna system developed under this program be improved and supplemented by (1) providing higher gain antennas (possibly stacked yagis) in the 30- to 60-megahertz region; (2) using the 30 foot RAT SCAT dishes and towers in the 60- to 250-megahertz region; and (3) providing automated controls for changing polarization.

5.3.2 Range Design

Based on the test results obtained during the demonstration and feasibility programs and the general recommendations discussed in subsection 5.3, recommendations are presented relative to the range design factors of range lengths, terrain condition, pit-rotator design, target supports, and secondary standard location.

Based on the results of the background test results it is recommended that (1) before the rotator pits are implemented the 30- to 100-megahertz equipment when optimized for pulse operation (5.3.1) be used to determine the optimum range location by conducting test using vertical polarization; (2) perform additional terrain leveling in connection with the test program in (1) to see if background improvement can be obtained over that obtainable with the present terrain conditions; (3) as determined from the tests in (1) locate a rotator pit at a relative short range, 800 to 1200 feet for operation in the 60- to 250-megahertz frequency region and one at a longer range 1500 to 2500 feet for operation below 60 megahertz; (4) supplement present target supports with additional supports which can handle loads up to 10,000 pounds and optimize for low cross section; and (5) determine location which will allow a secondary standard to be implemented where minimum bistatic effects are produced and adequate sensitivity can be realized.

5.3.3 Operational Considerations

The recommendations presented in paragraphs 5.3.1 and 5.3.2 are designed primarily to provide an optimum measurement capability at RAT SCAT by modifications on and/or tests performed with the present VHF equipment and/or existing RAT SCAT equipment. However, to obtain an operational facility commensurate with present RAT SCAT standards, additional provisions must also be made. Although the list below is not complete, the major items which need to be provided are delineated.

The major items currently not available at the VHF location are (1) permanent power (a portable generator was used during the study); (2) a RF shielded structure for the electronic

system; (3) power controls for antennas for obtaining optimum isolation; (4) cross section, phase and data control consoles; (5) 50- to 100-megahertz feeds for 30 foot dishes; (6) a secondary standard; (7) pits, rotators, and target supports capable of handling targets up to 10,000 pounds; and (8) provision for handling targets up to 65 foot heights.

If the items indicated above are provided and the recommendation discussed earlier are implemented, a fully operational VHF measurement facility (30 to 250 megahertz) can be realized at RAT SCAT in which background levels, target handling capability, and measurement accuracies, will be commensurate with the current capability at the higher frequencies.

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2. VHF Radar Cross Section Measurement Feasibility System, General Dynamics, Fort Worth Division, Report No. FZE-574, 17 October 1966.

3. Kerr, D. E., Propagation of Short Radio Waves, Radiation Laboratory Series, Volume 13, McGraw-Hill, Inc., 1951.

4. Theoretical and Experimental Investigation of a Technique for Reducing Extraneous Signals in Radar Scattering Measurements, Technical Documentary Report No. RADC-TDR-64-418, AD No. 607 136 July, 1964.

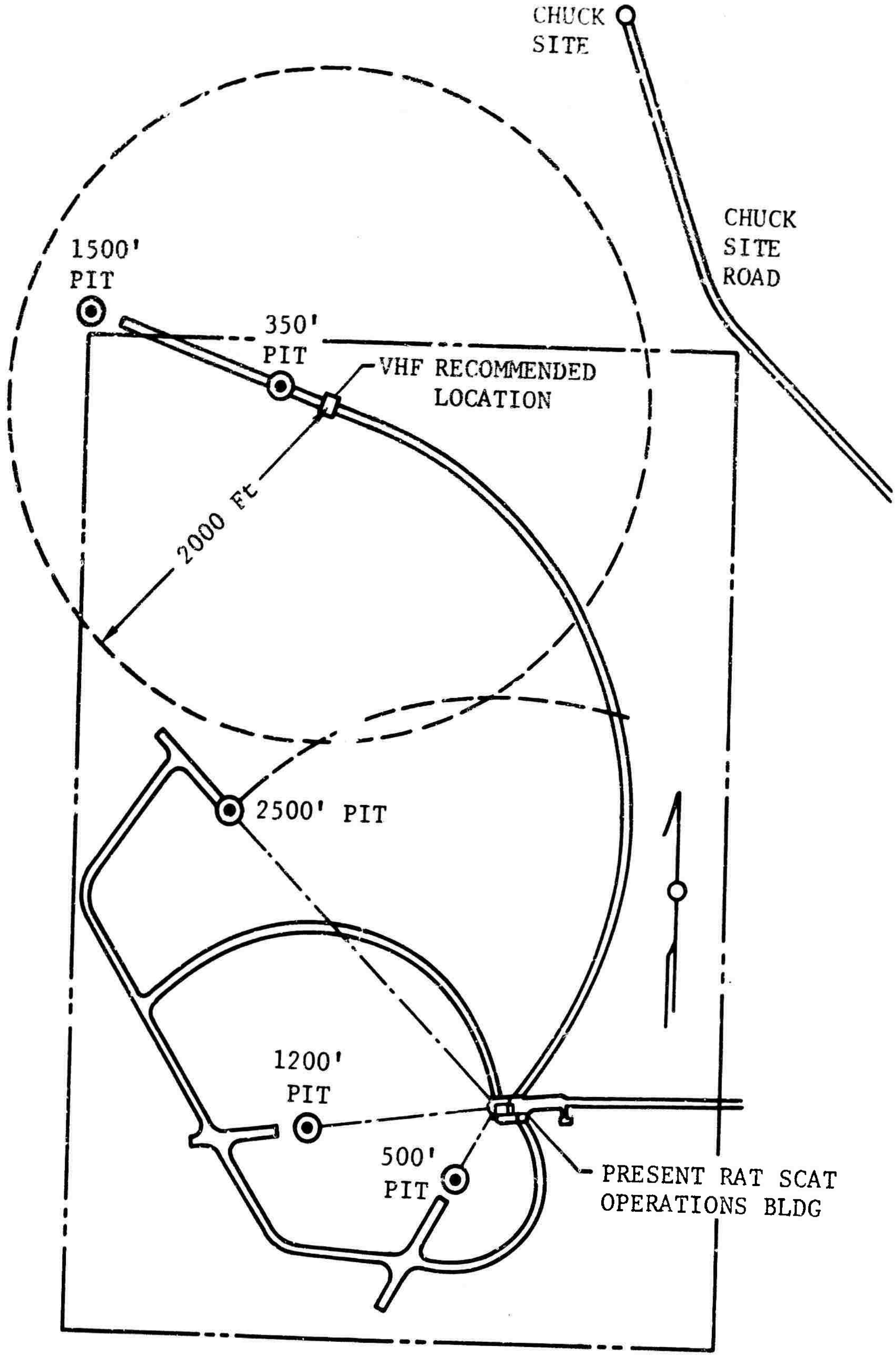


Fig. 1 VHF RANGE

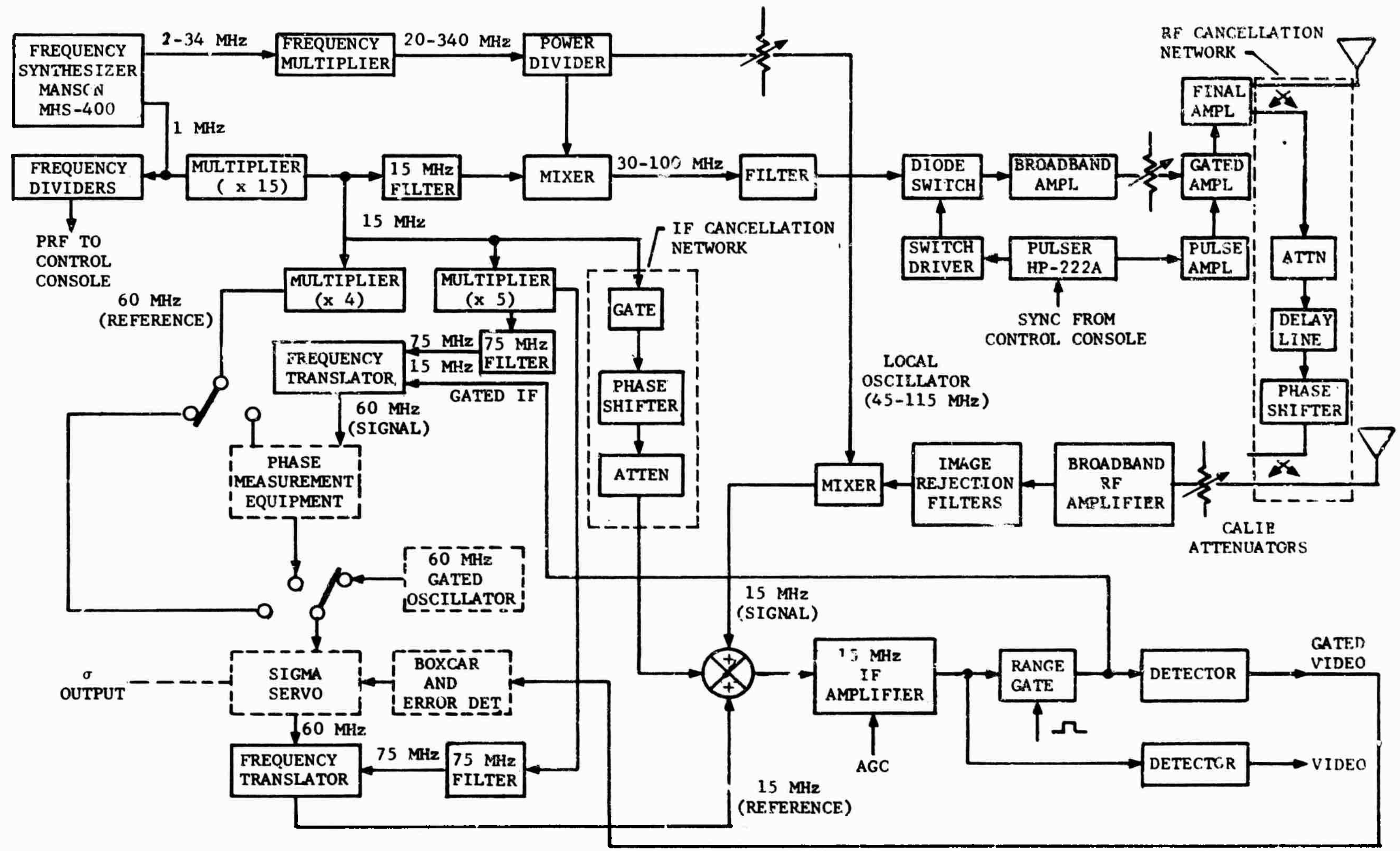


Figure 2. VHF ELECTRONIC SYSTEM DIAGRAM

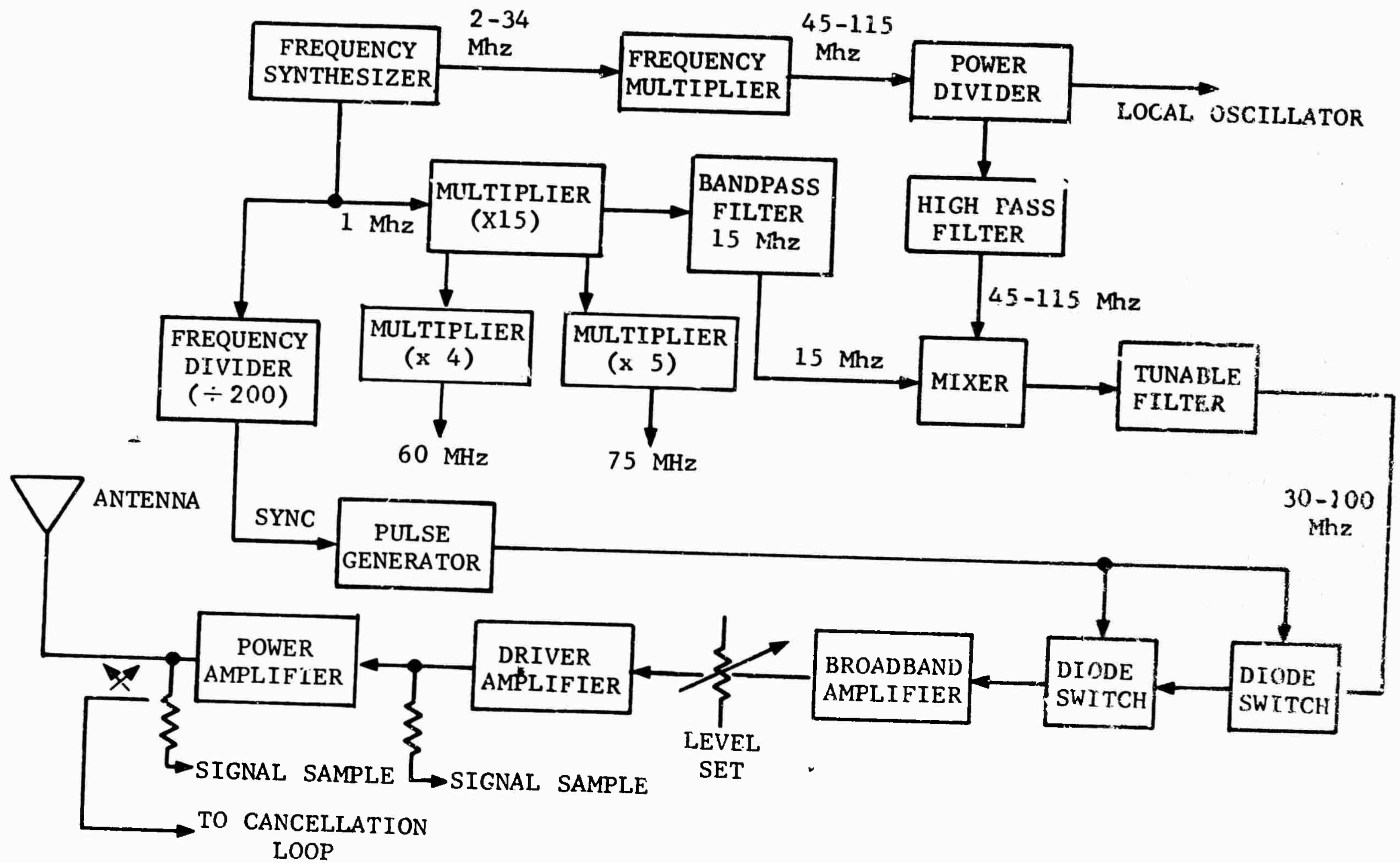


Fig. 3 TRANSMITTER BLOCK DIAGRAM

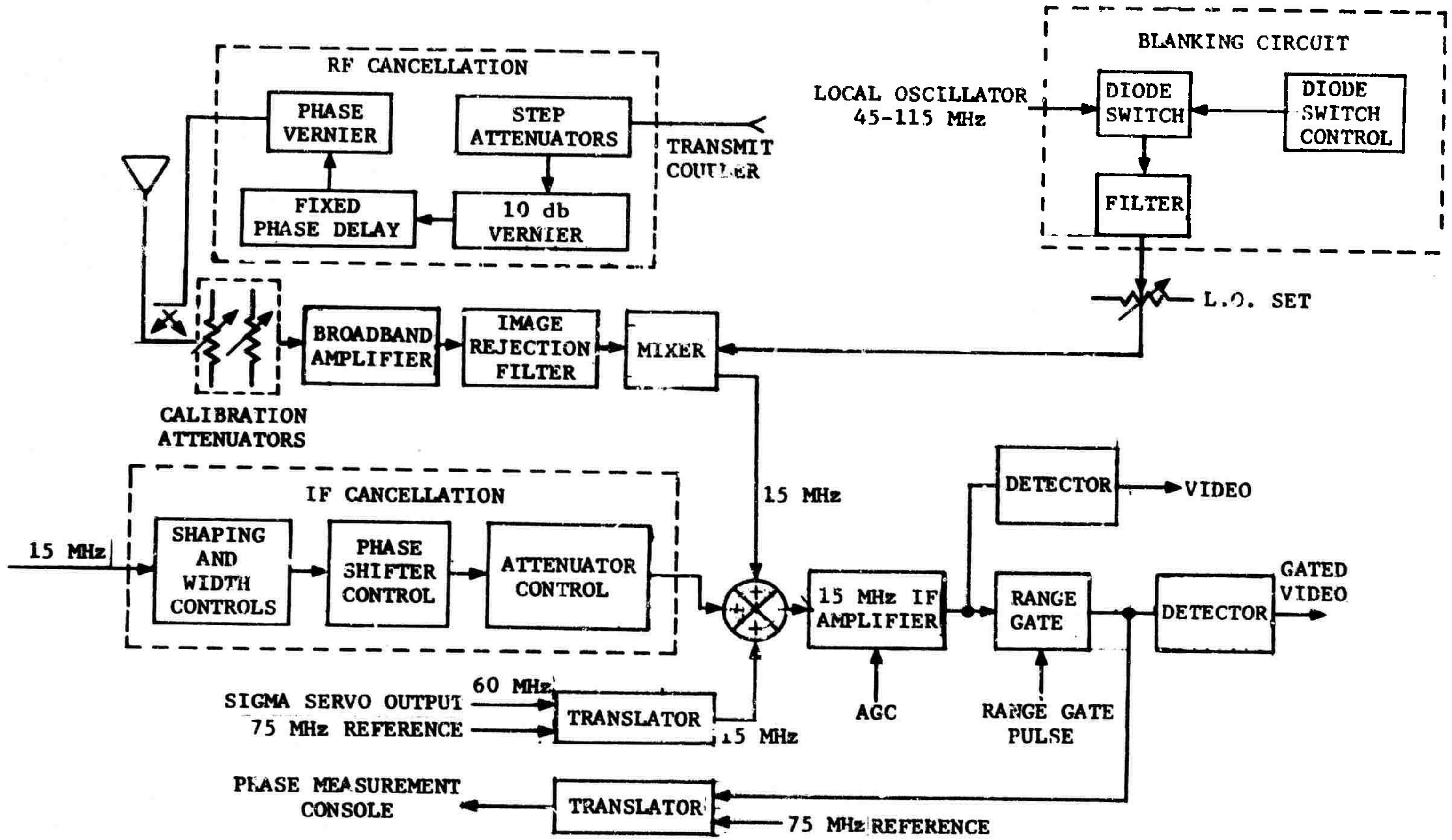


Figure 4. RECEIVER BLOCK DIAGRAM

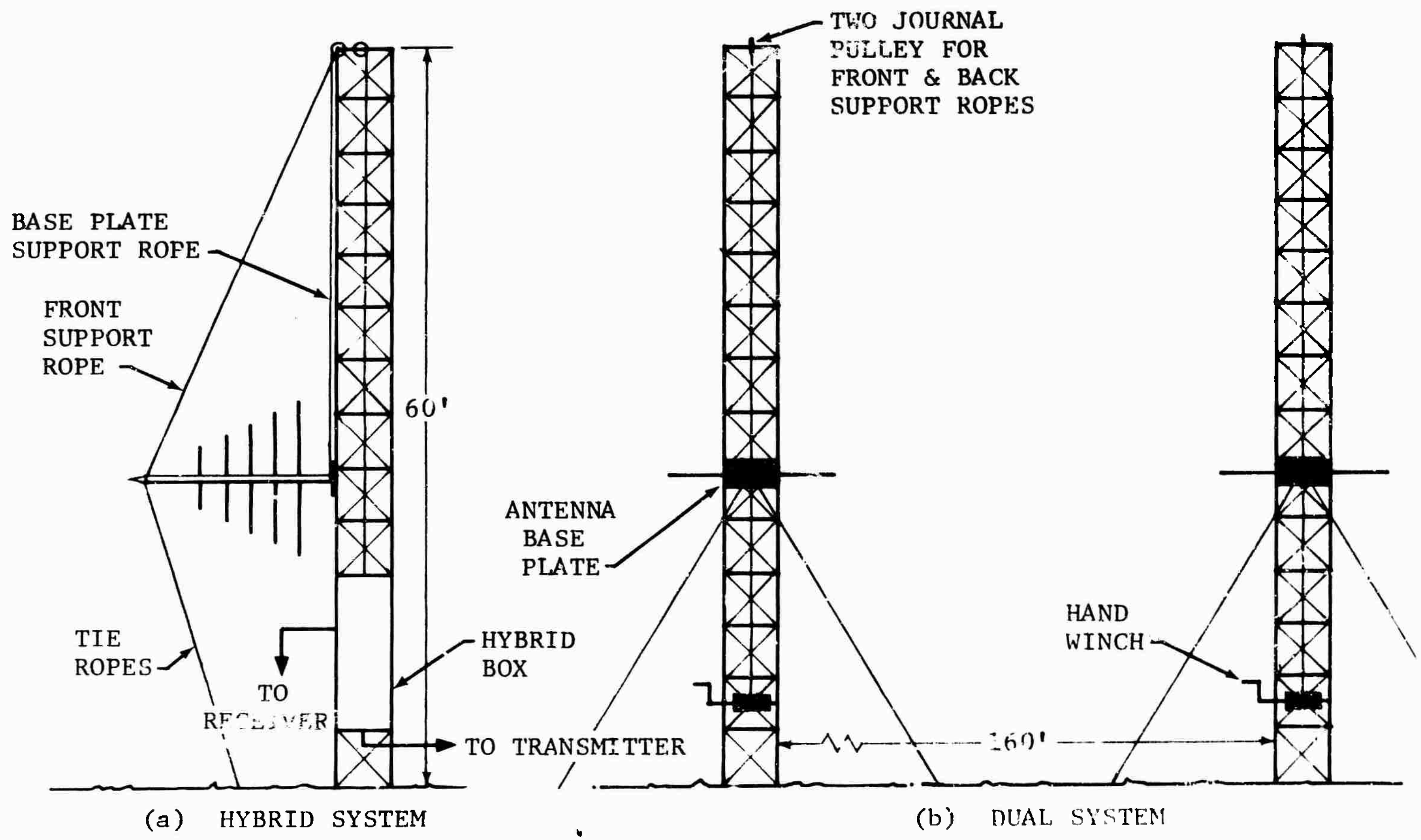


Figure 5. ANTENNA SYSTEM DESIGN

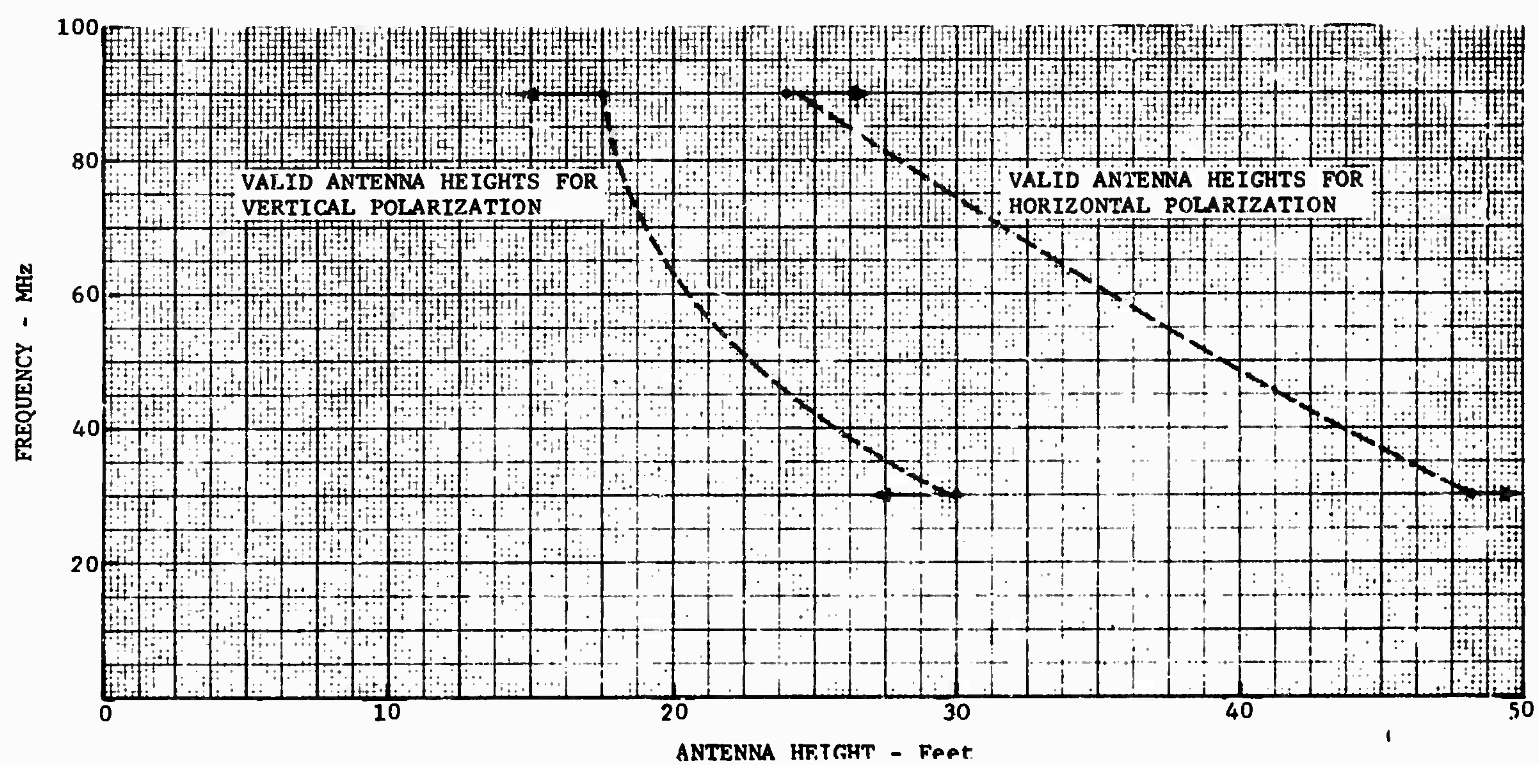


Figure 6. ANTENNA HEIGHTS FOR SHORT RANGE DESIGN

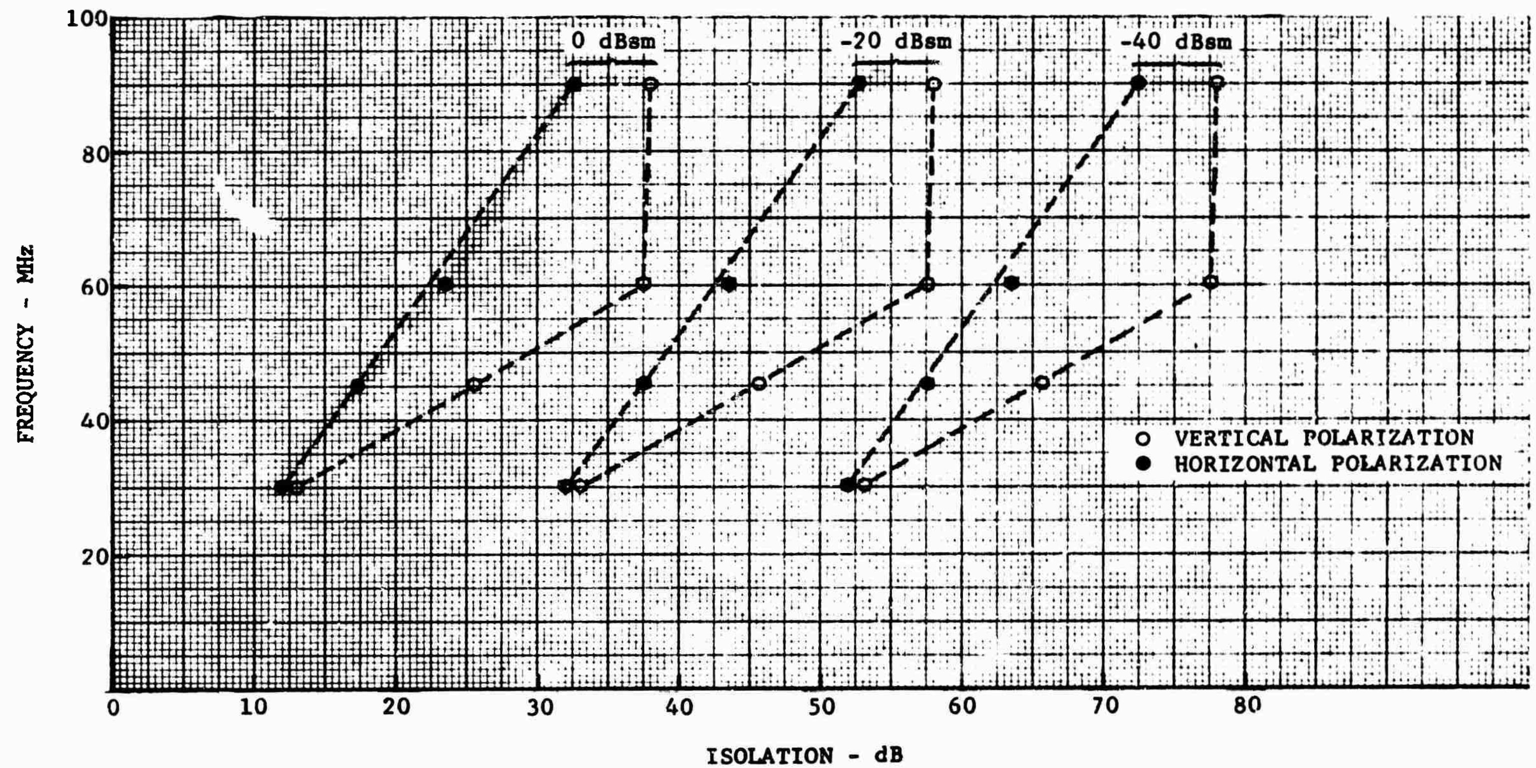


Figure 7. ISOLATION REQUIREMENTS FOR HYBRID SYSTEM

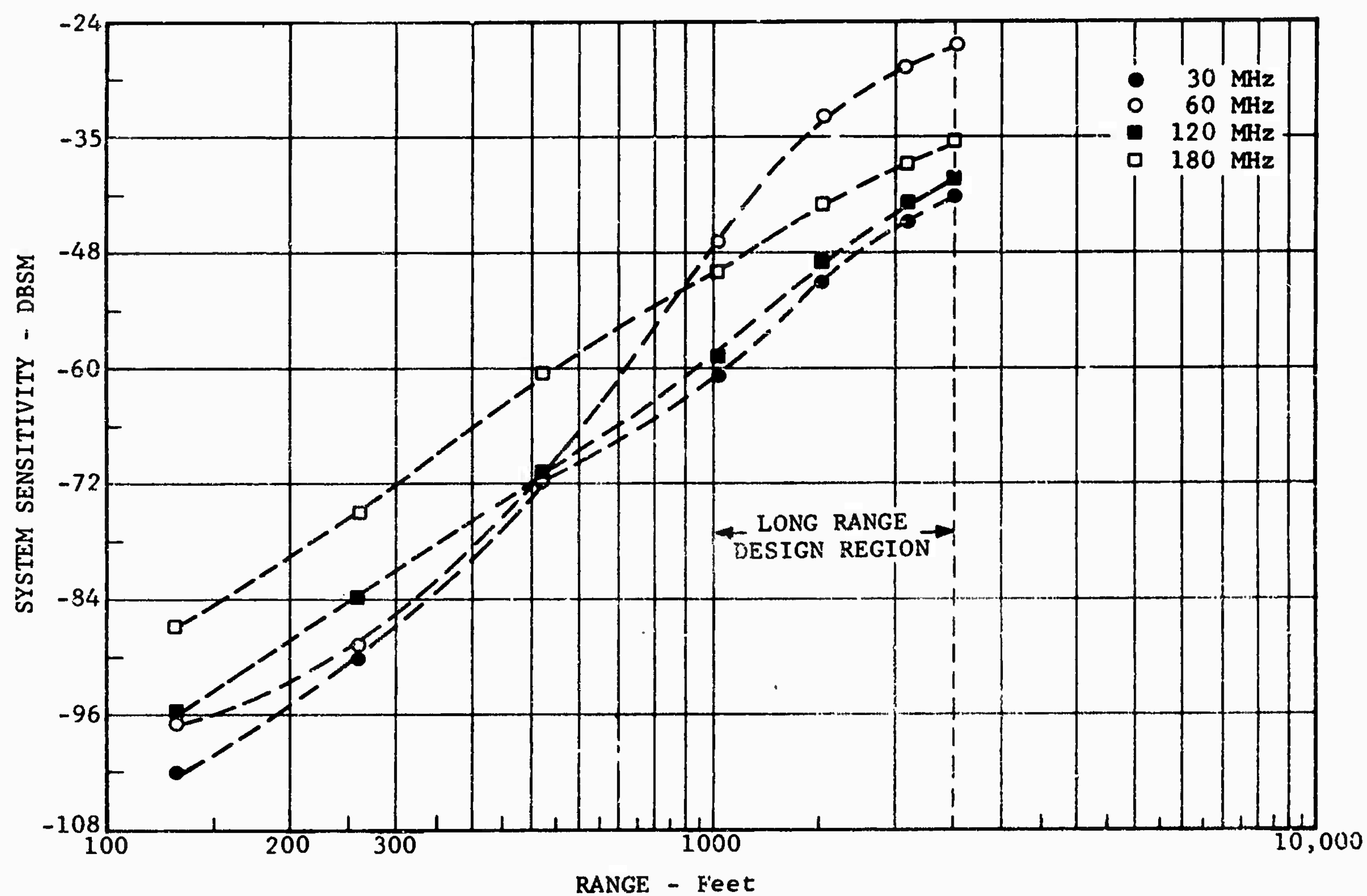


Fig. 8 LONG RANGE DESIGN SENSITIVITY (VERTICAL POLARIZATION)

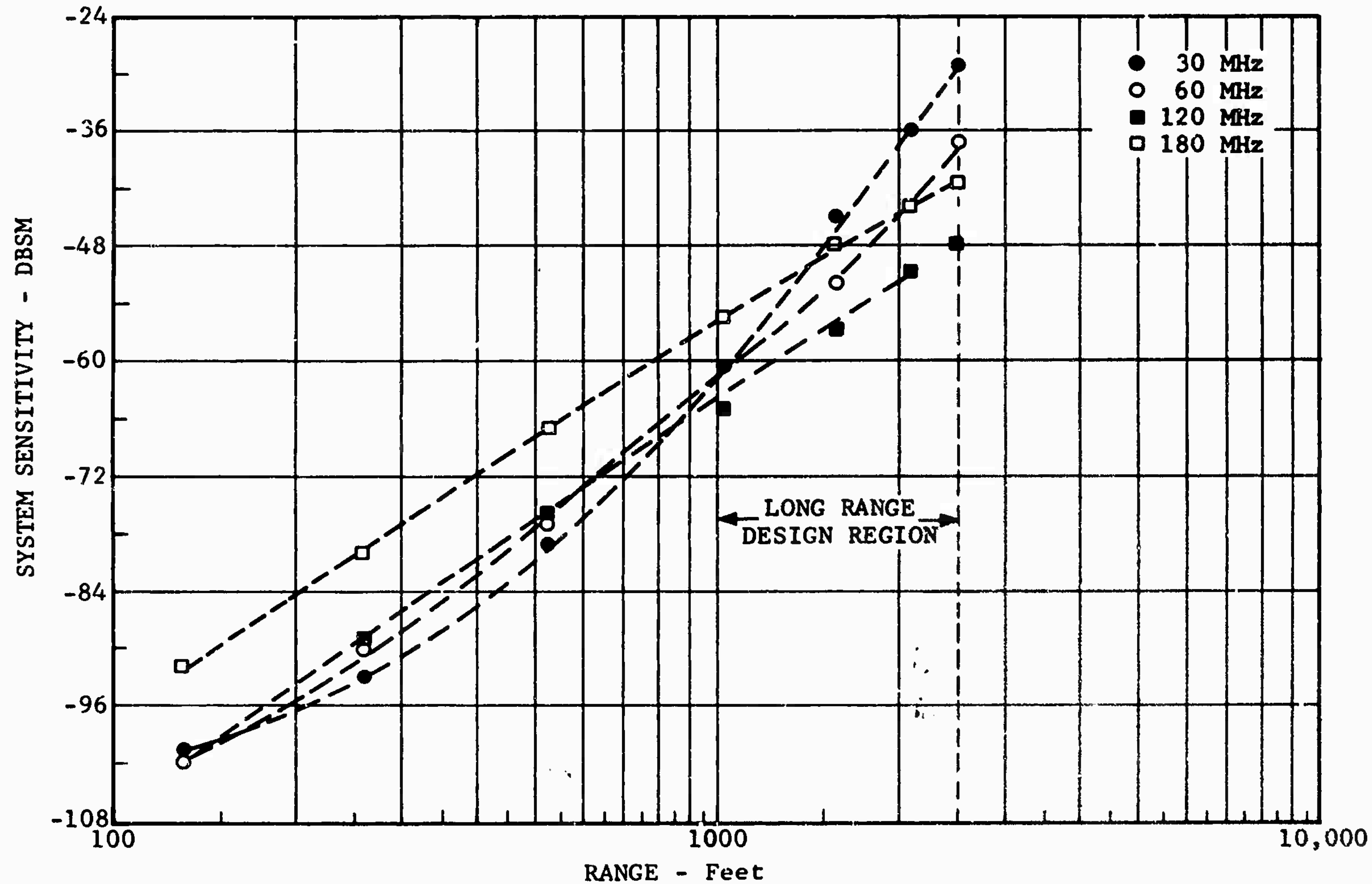


Fig. 9 LONG RANGE DESIGN SENSITIVITY (HORIZONTAL POLARIZATION)

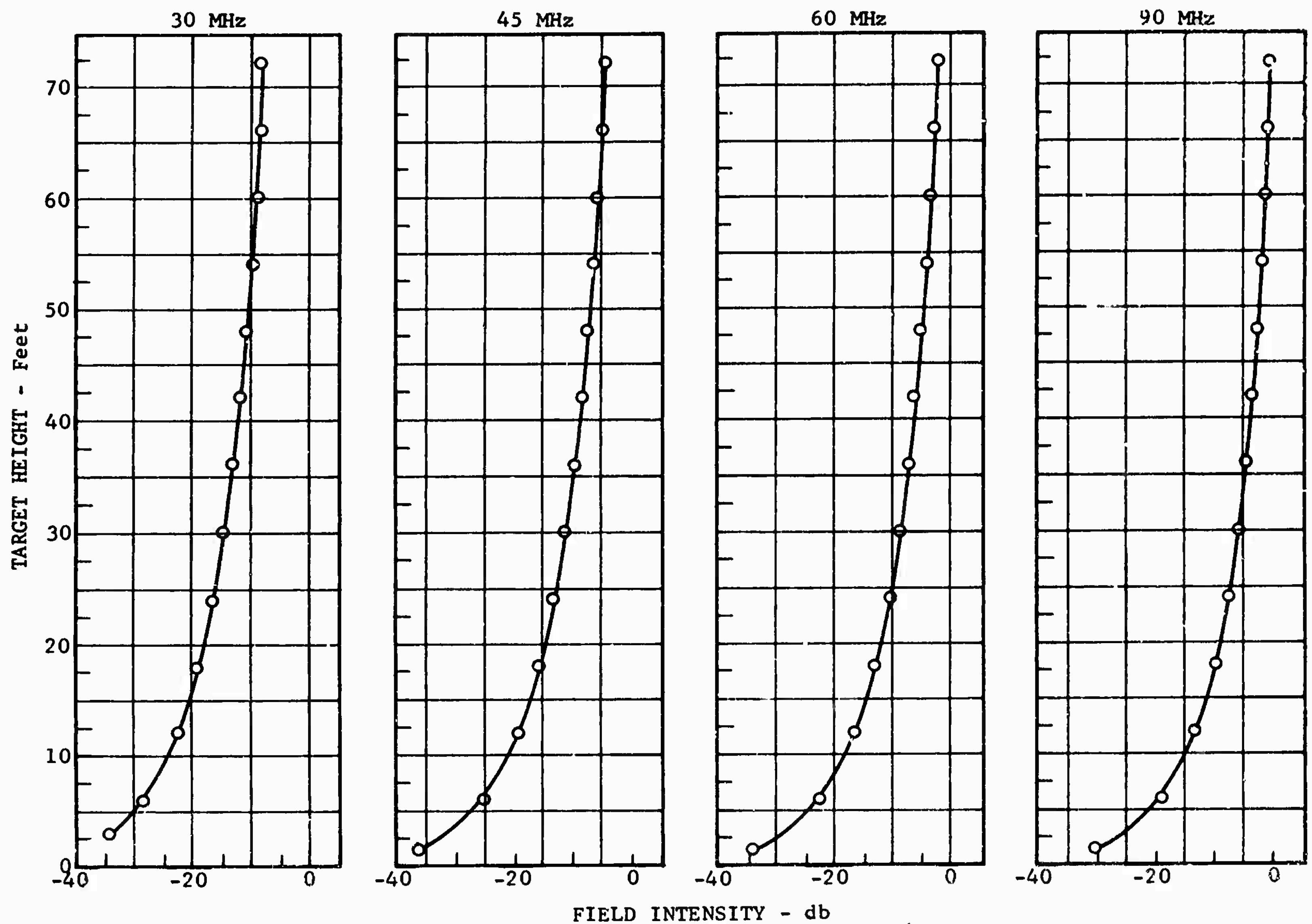


Fig. 10 LONG RANGE FIELD GRADIENTS (HORIZONTAL POLARIZATION)

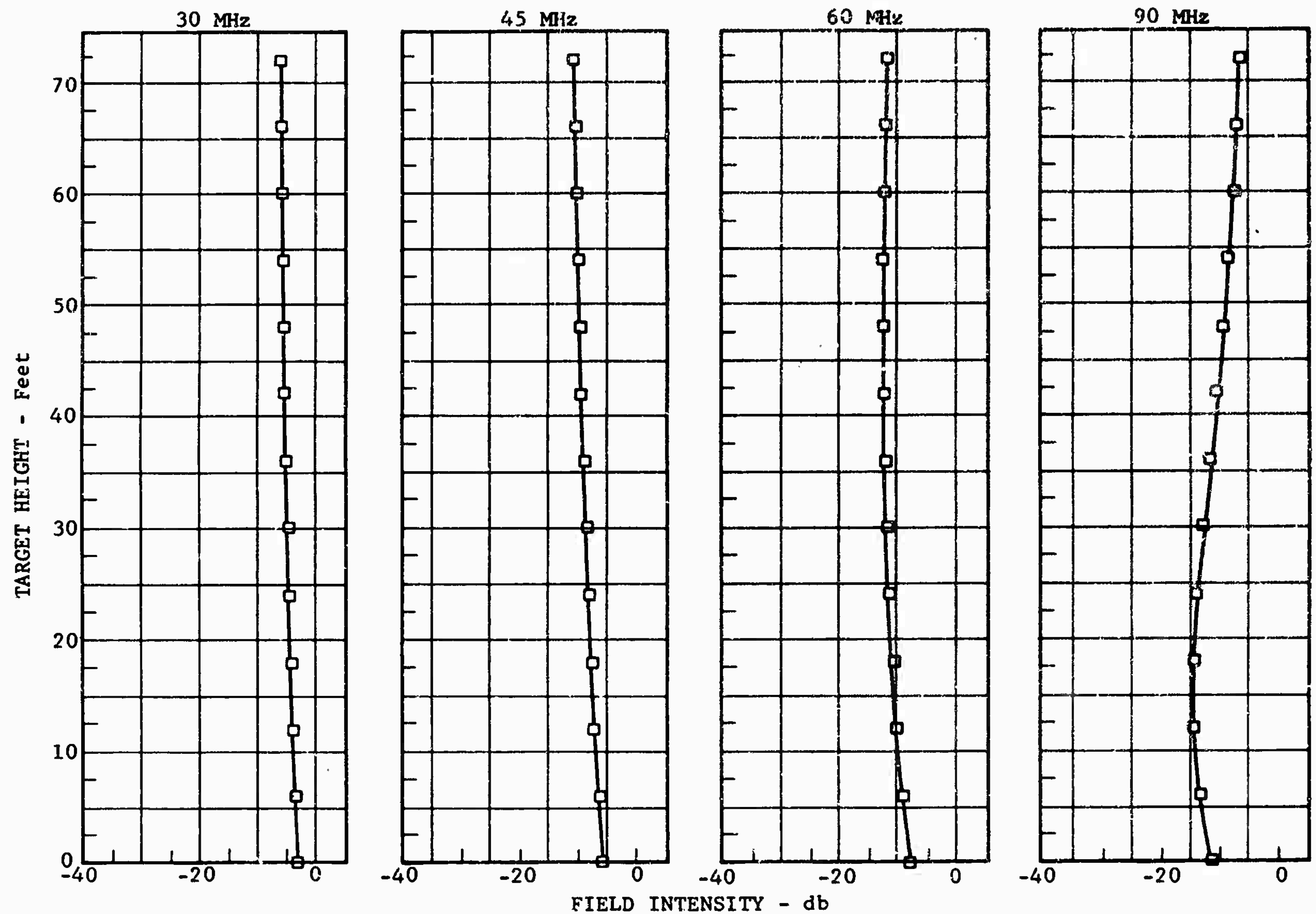


Fig. 11 LONG RANGE FIELD GRADIENTS (HORIZONTAL POLARIZATION)

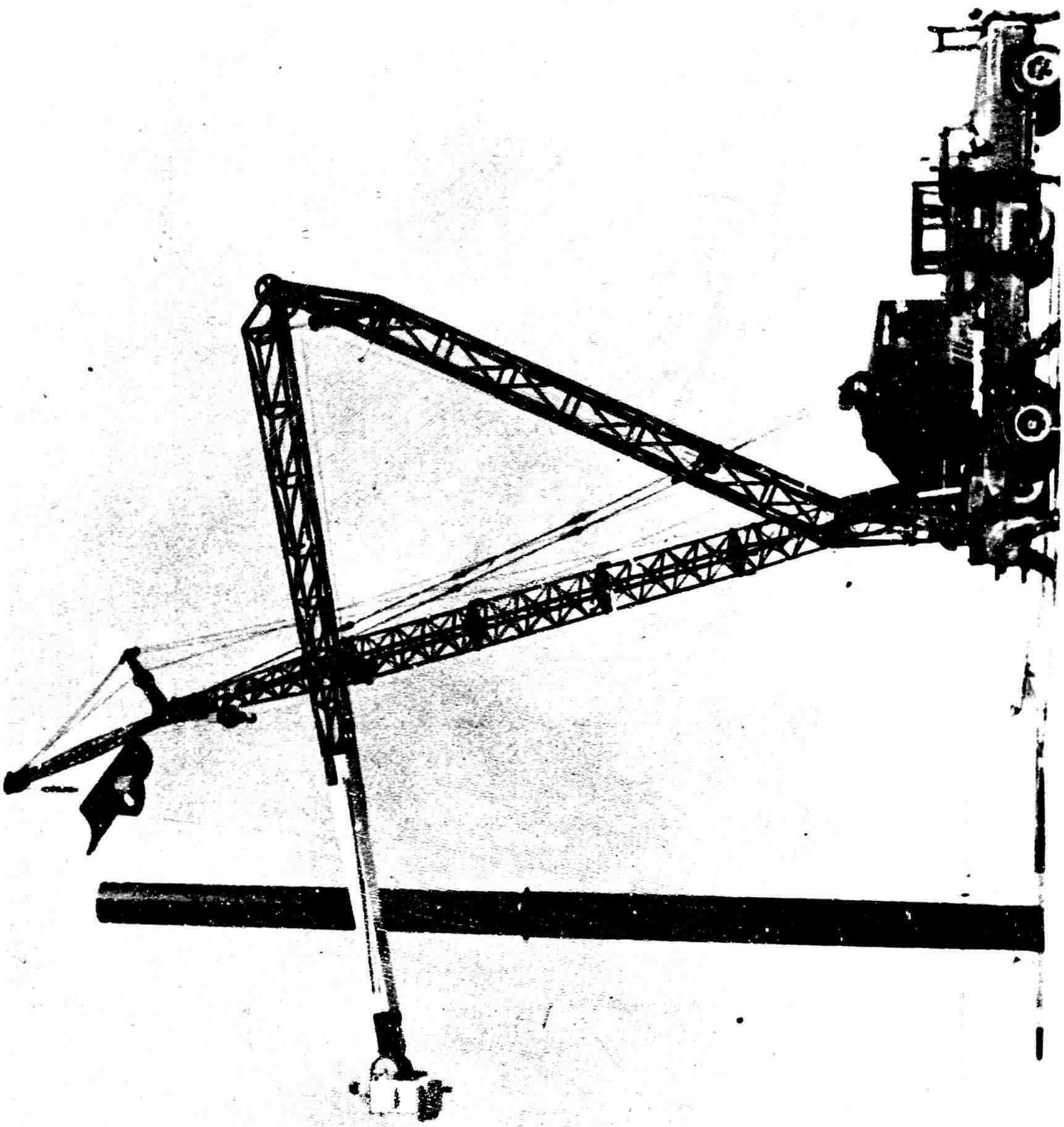


Fig. 12 FIBER GLASS TARGET SUPPORT

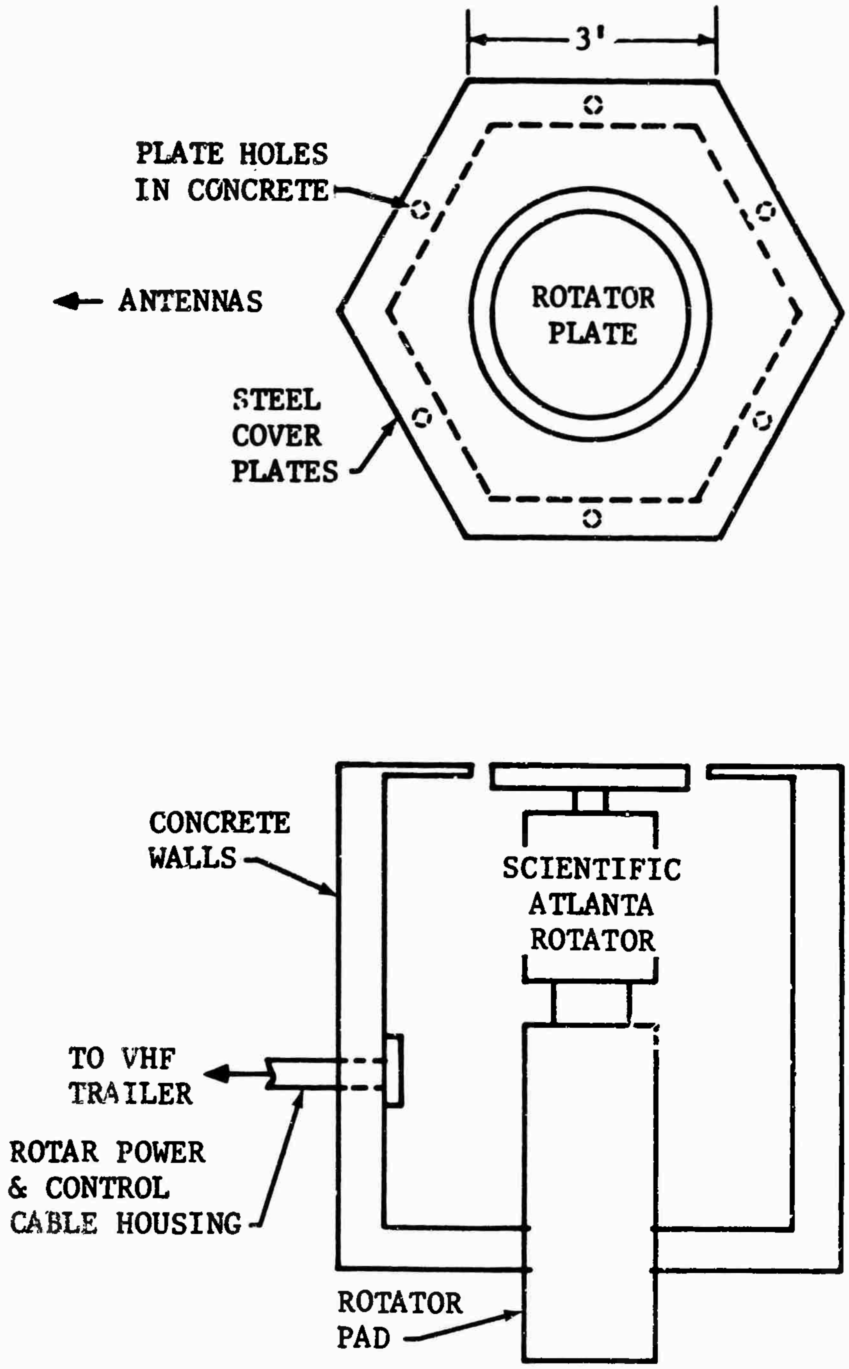


Fig. 13 ROTATOR AND PIT DESIGN

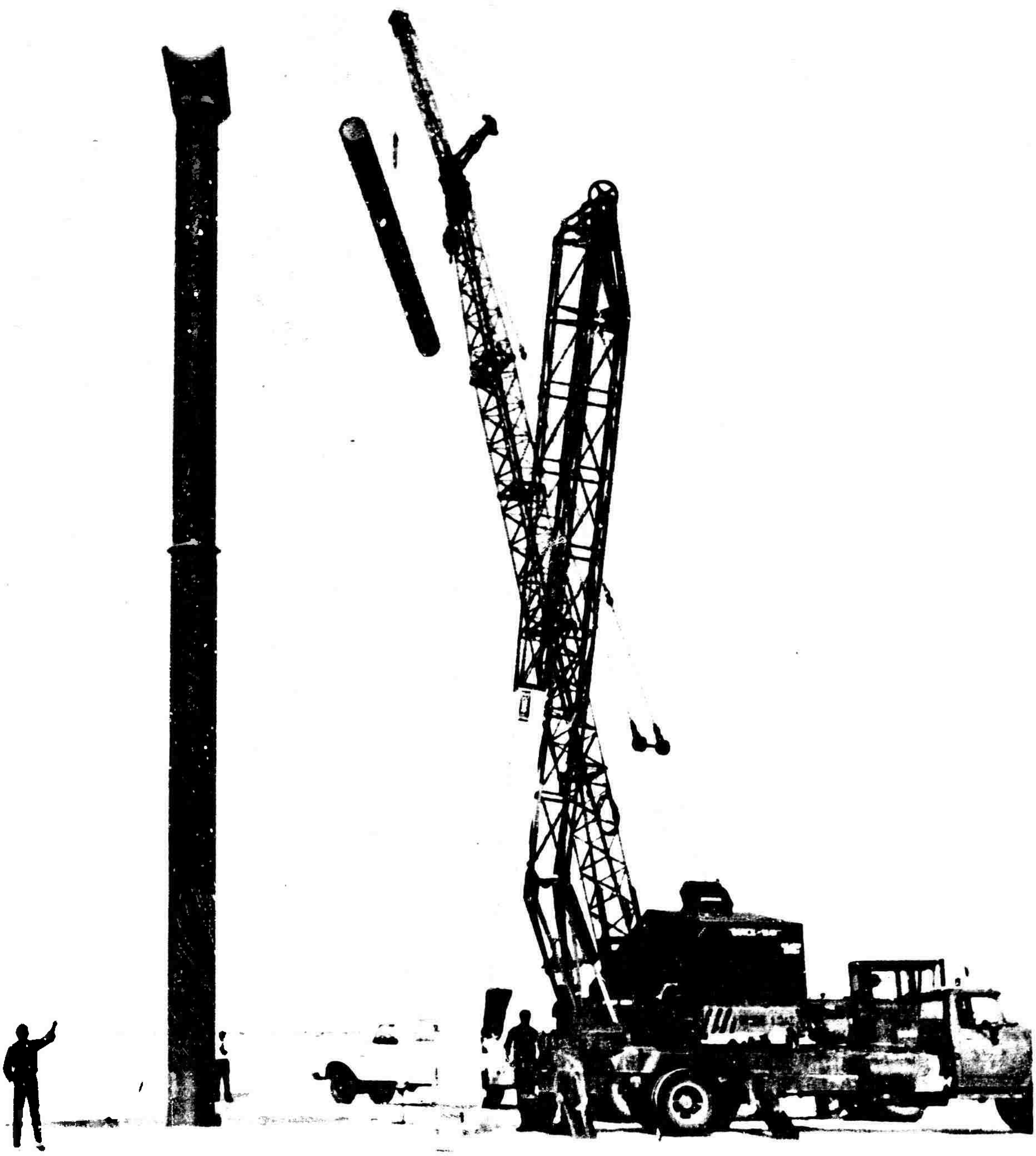


Figure 14. TEST TARGET AND SUPPORT COLUMN

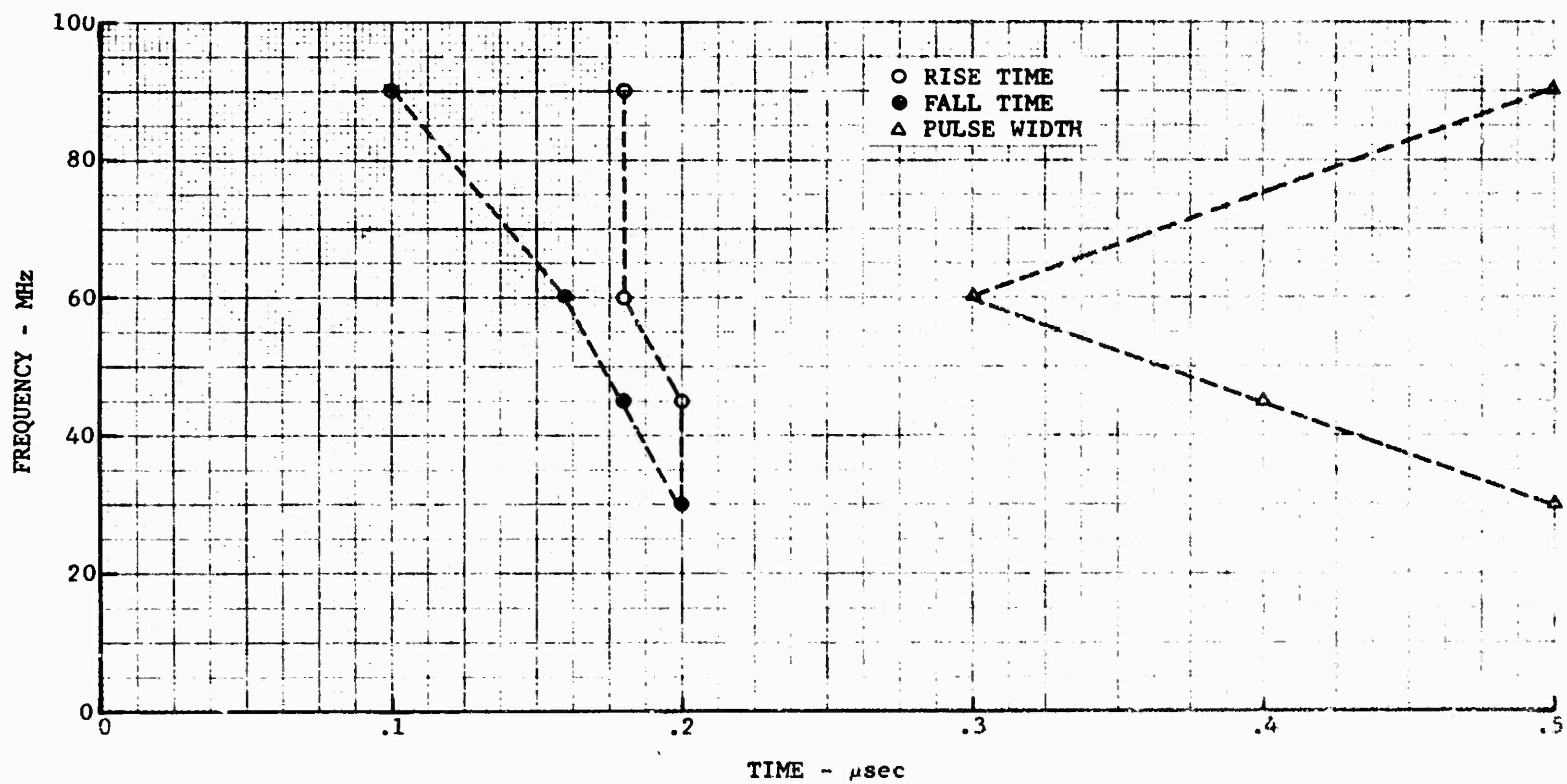


Figure 15. PULSE CHARACTERISTICS

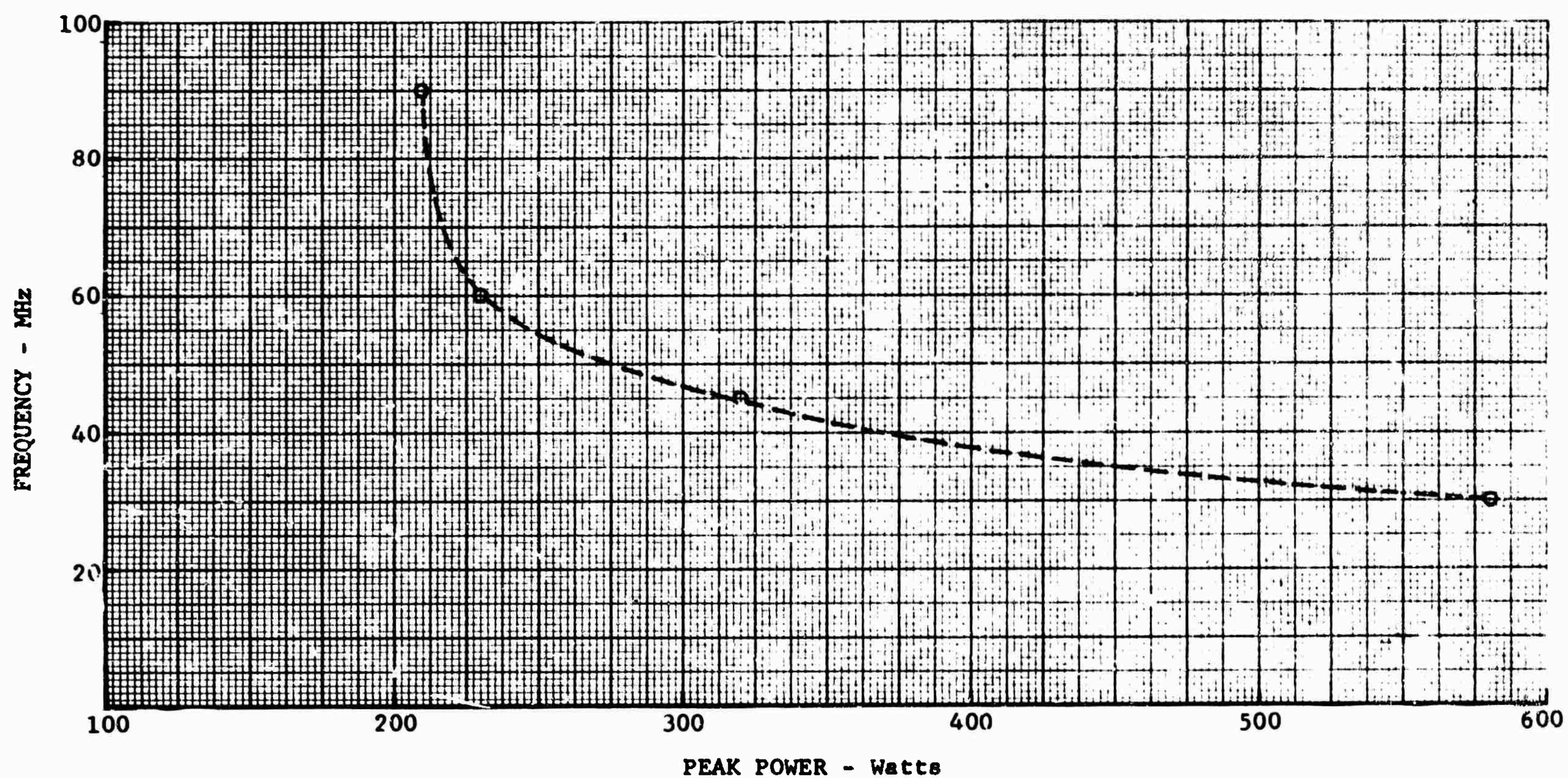


Figure 16. TRANSMITTER POWER OUTPUT

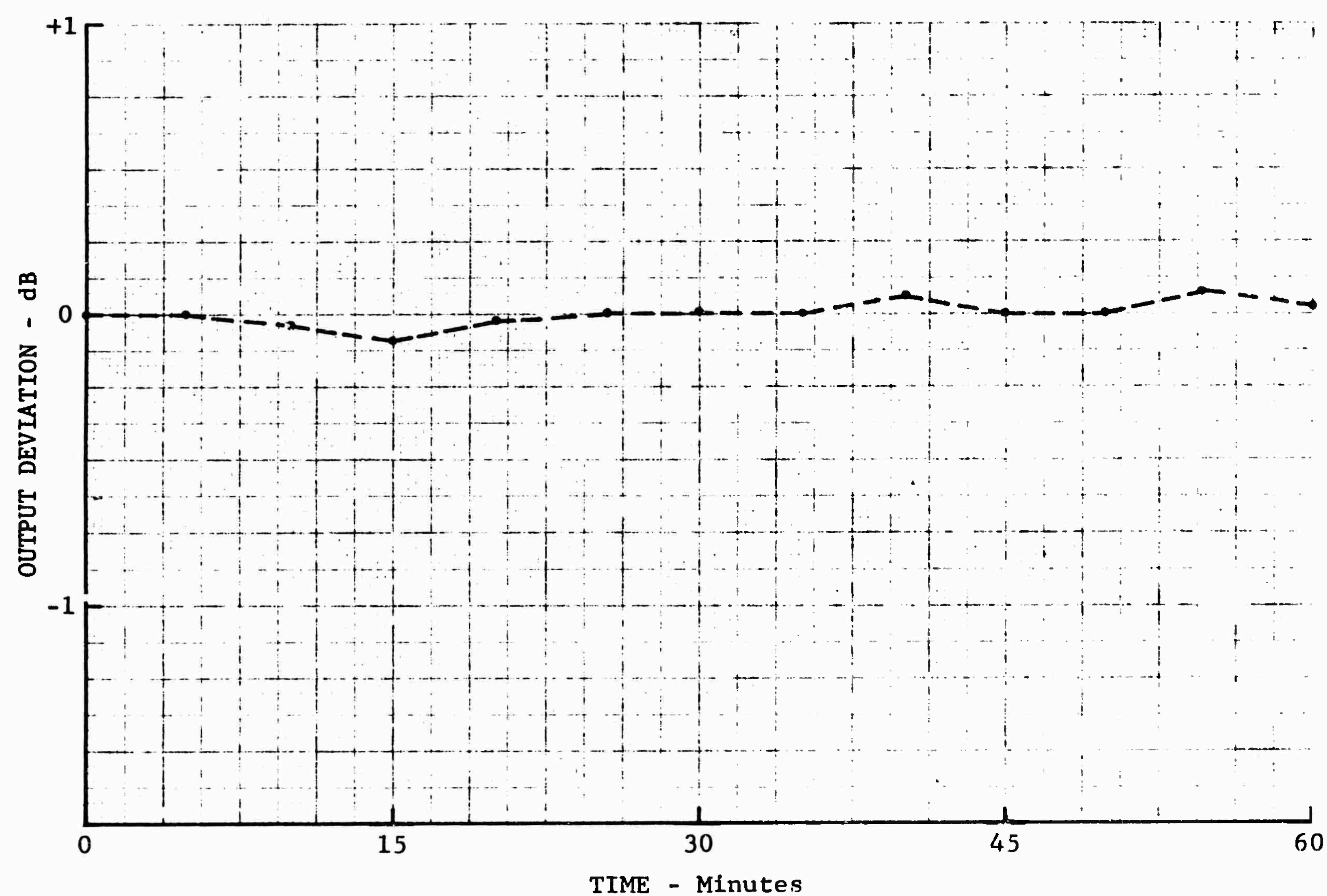


Fig. 17 TRANSMITTER STABILITY

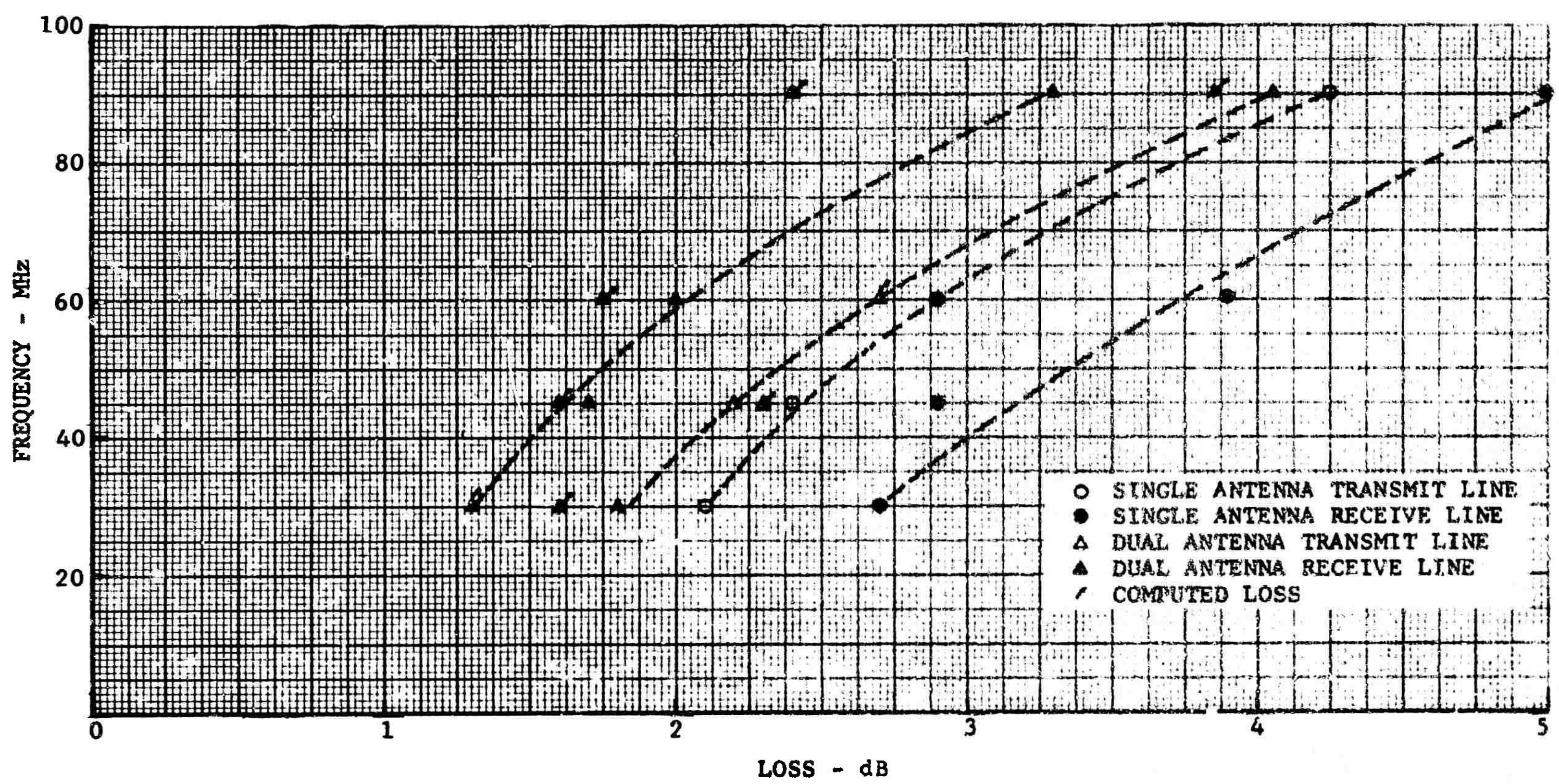


Figure 18. LINE LOSSES

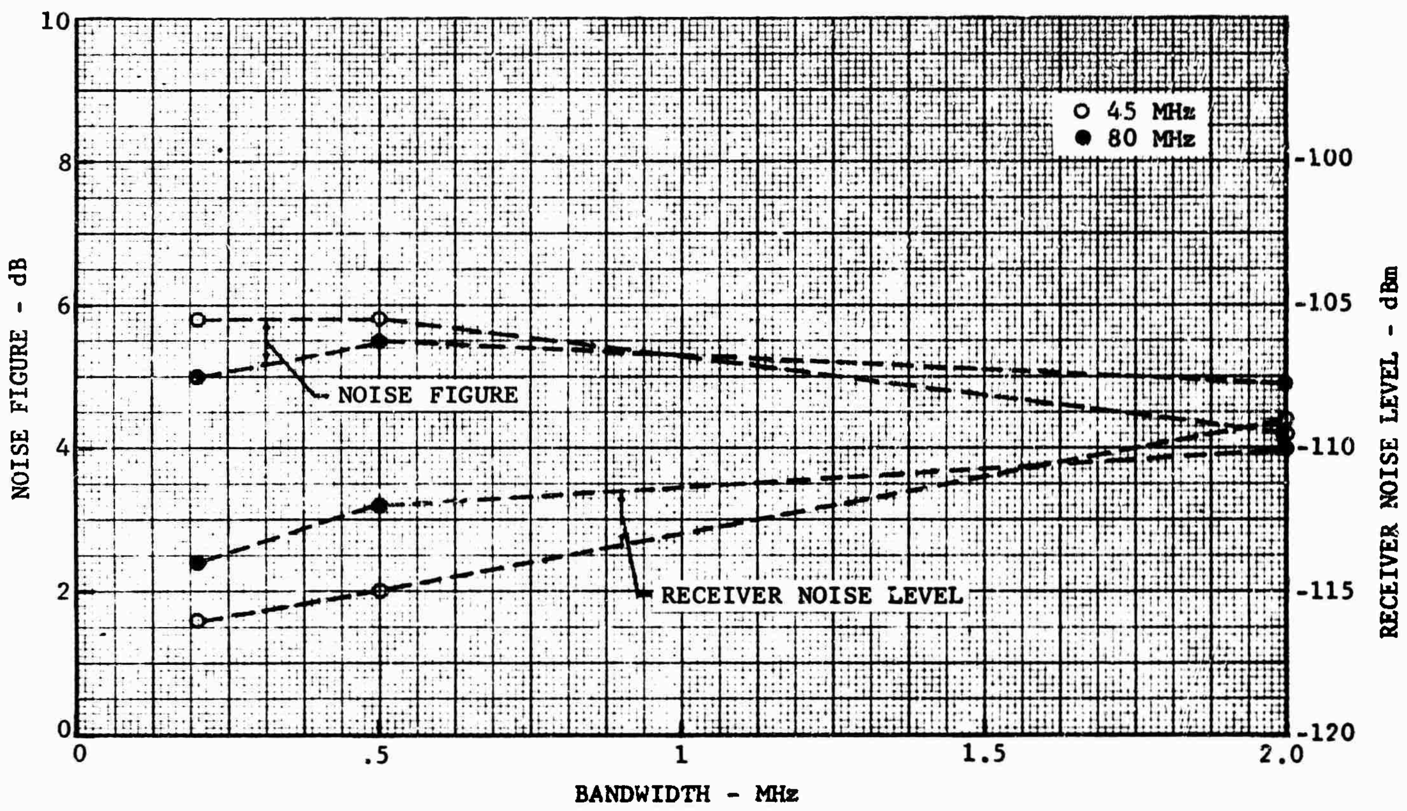


Figure 19. RECEIVER NOISE FIGURE AND LEVEL

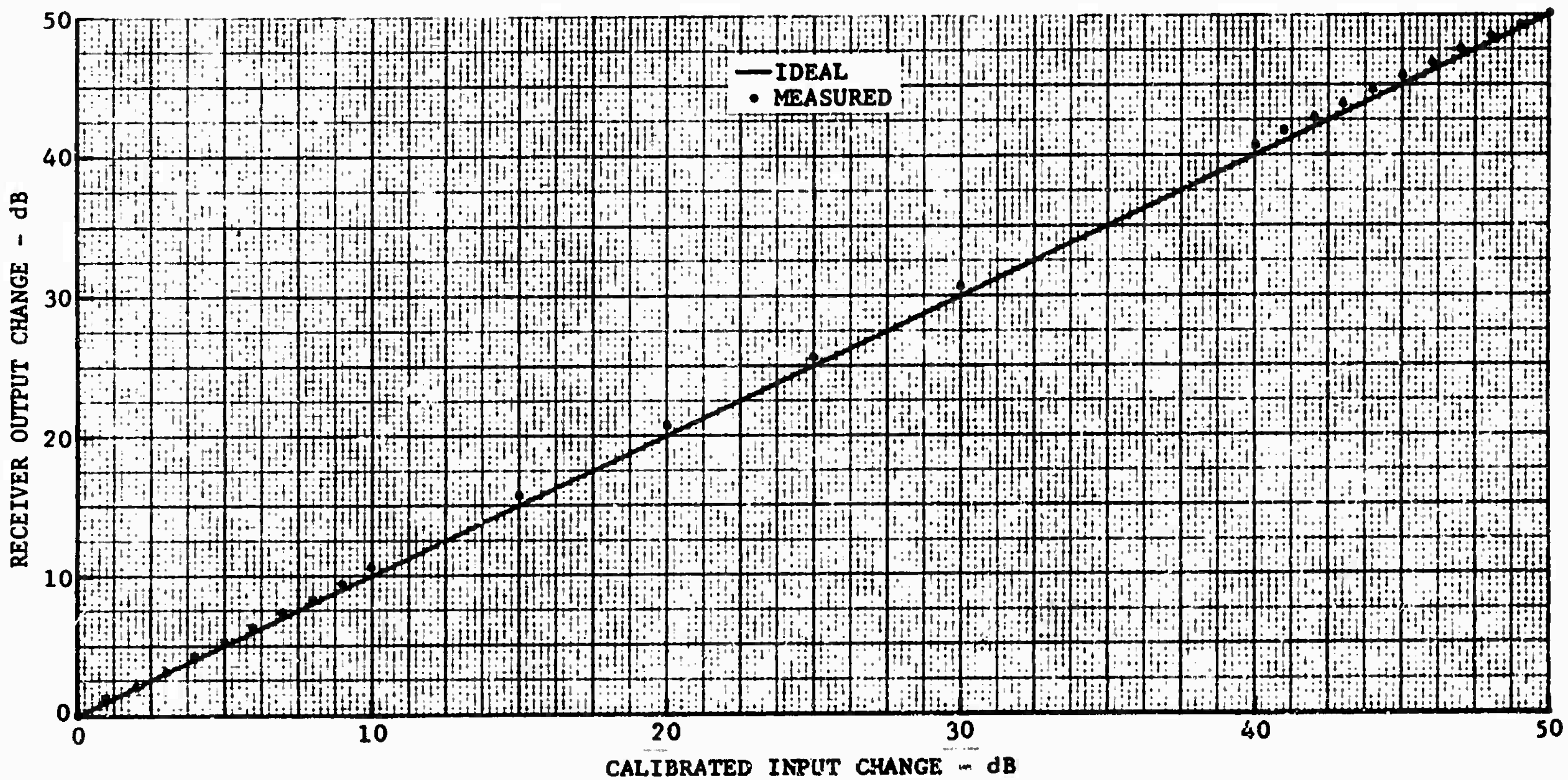


Figure 20, RECEIVER LINEARITY

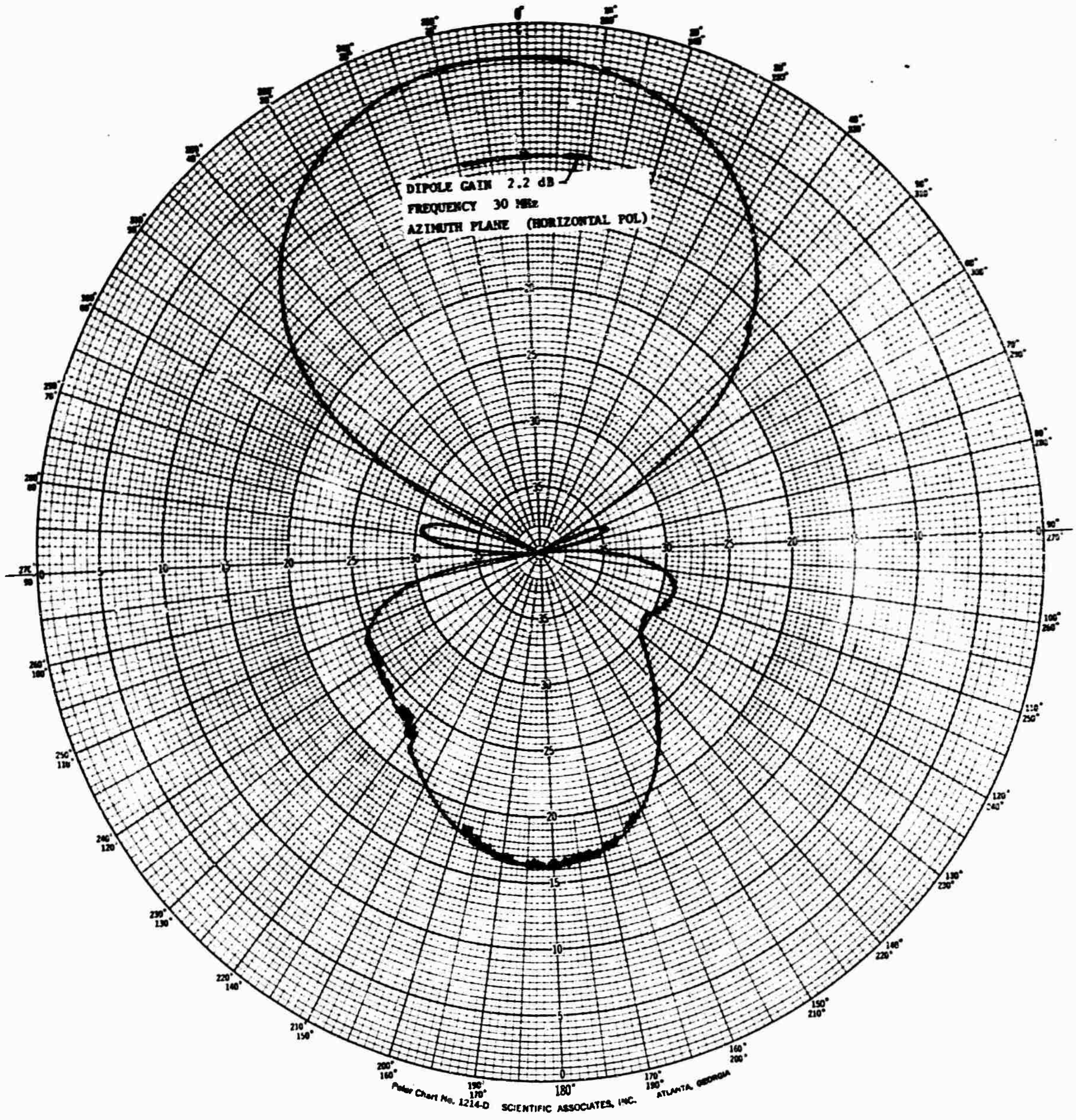

DIPOLE GAIN 2.2 dB
FREQUENCY 30 MHz
AZIMUTH PLANE (HORIZONTAL POL)
Polar Chart No. 1214-D SCIENTIFIC ASSOCIATES, INC. ATLANTA, GEORGIA

Figure 21.

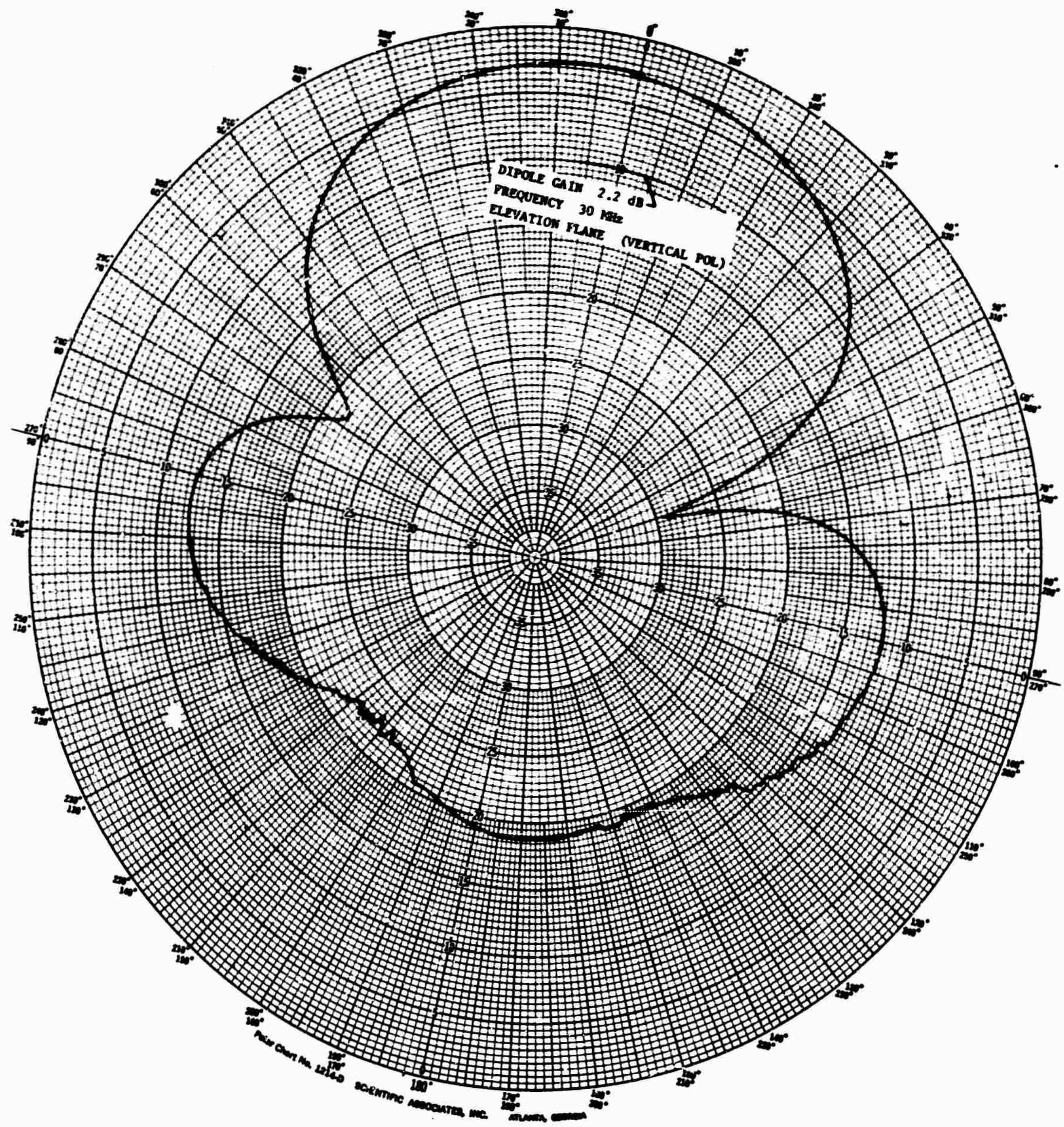

DIPOLE GAIN 2.2 dB
FREQUENCY 30 MHz
ELEVATION PLANE (VERTICAL POL)

Figure 22

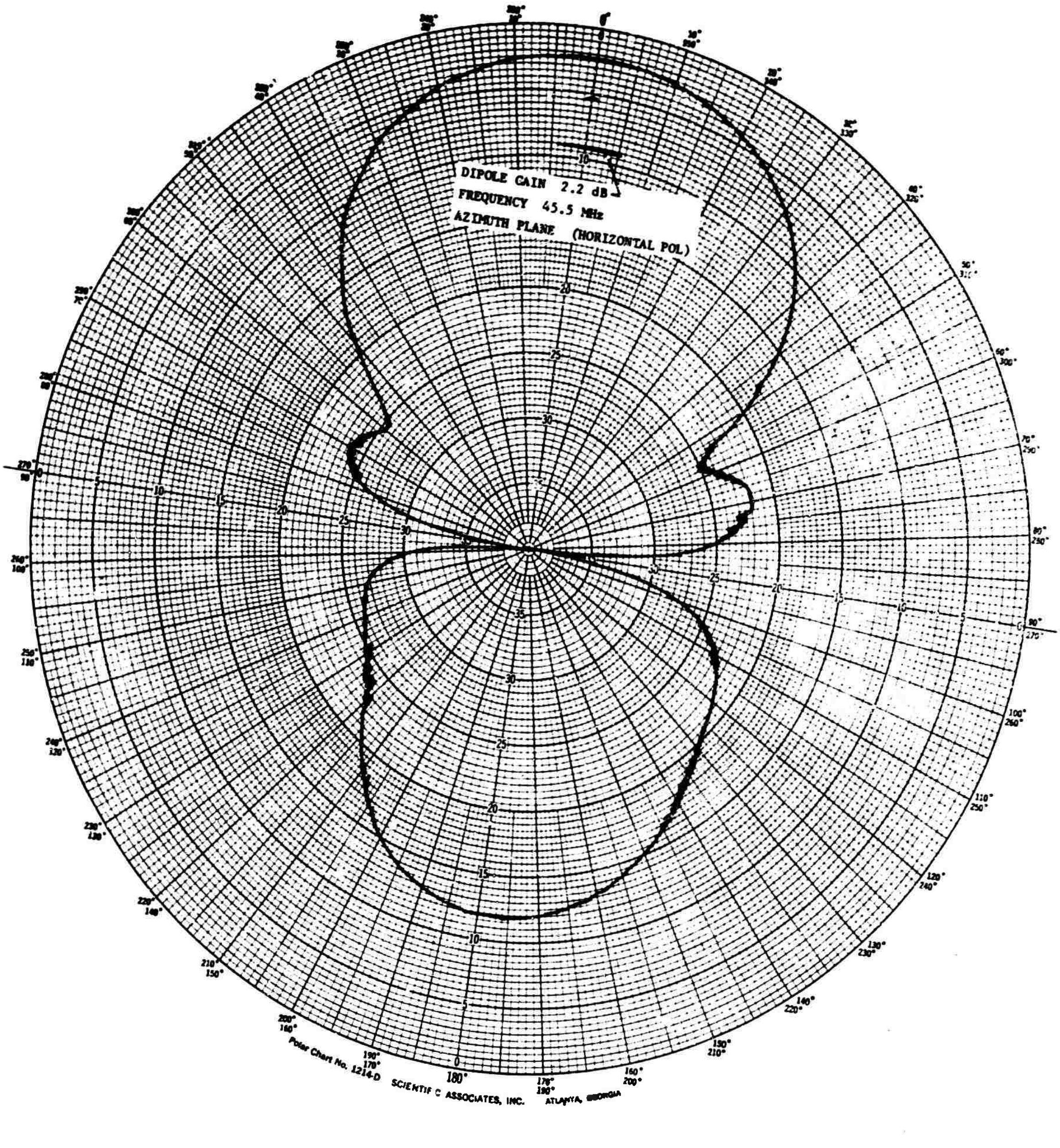

DIPOLE GAIN 2.2 dB
FREQUENCY 45.5 MHz
AZIMUTH PLANE (HORIZONTAL POL)
Polar Chart No. 1214-D
SCIENTIFIC ASSOCIATES, INC.
ATLANTA, GEORGIA

Figure 23

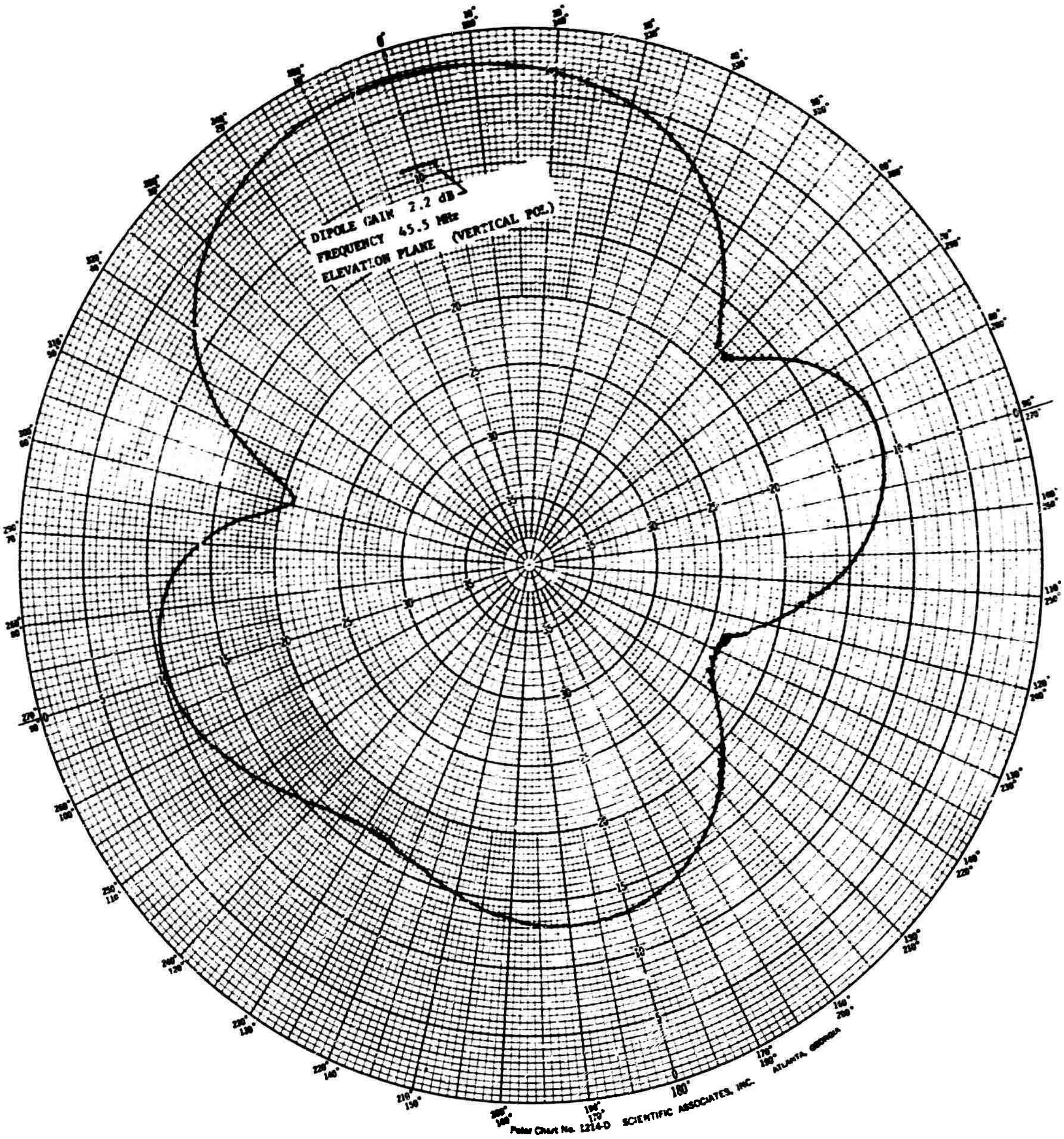

DIPOLE GAIN 2.2 dB
FREQUENCY 45.5 MHz
ELEVATION PLANE (VERTICAL POL.)
Polar Chart No. 1214-D SCIENTIFIC ASSOCIATES, INC. ATLANTA, GEORGIA

Figure 24

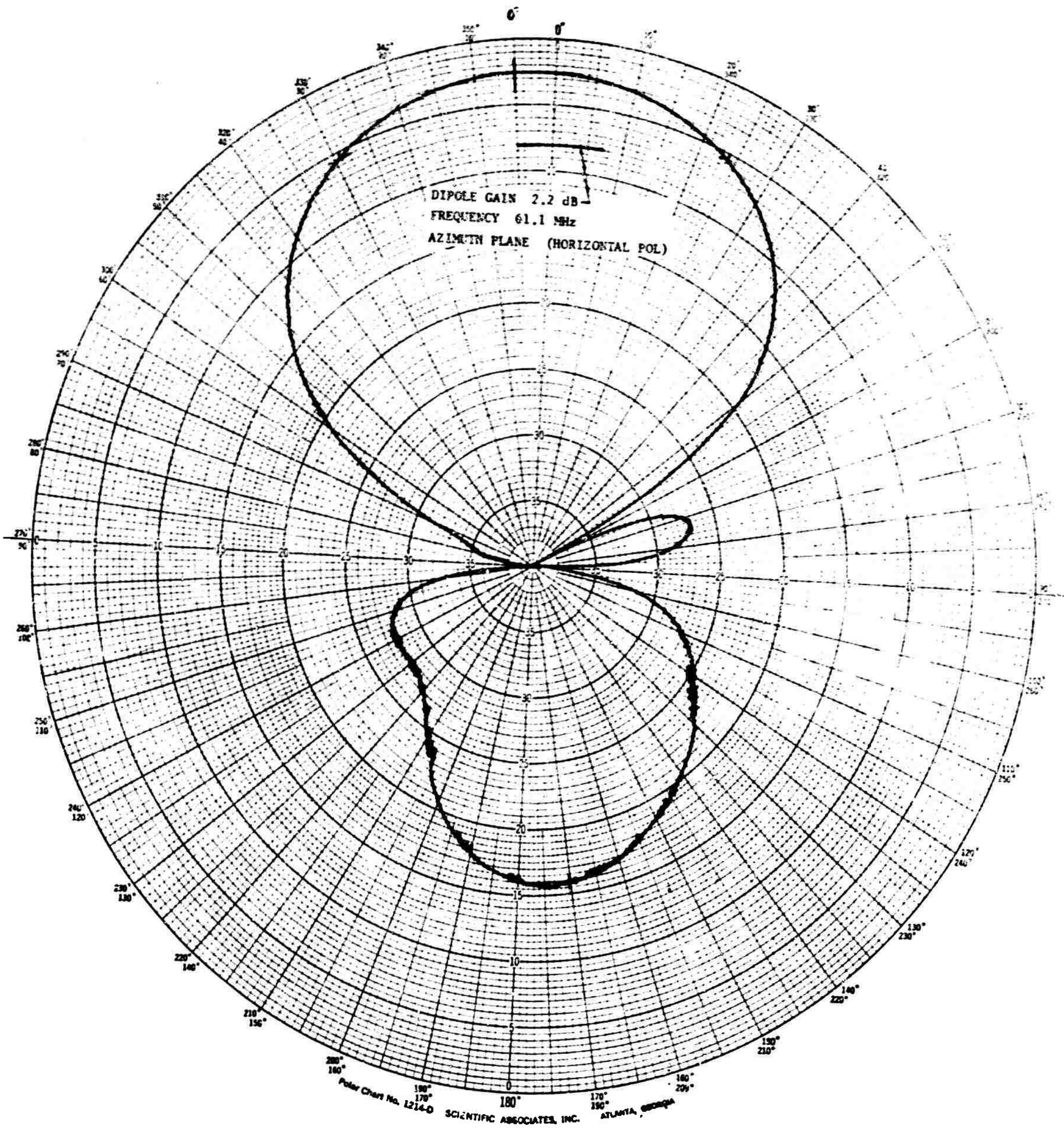

DIPOLE GAIN 2.2 dB
FREQUENCY 61.1 MHz
AZIMUTH PLANE (HORIZONTAL POL)
Polar Chart No. 1214-D SCIENTIFIC ASSOCIATES, INC. ATLANTA, GEORGIA

Figure 25

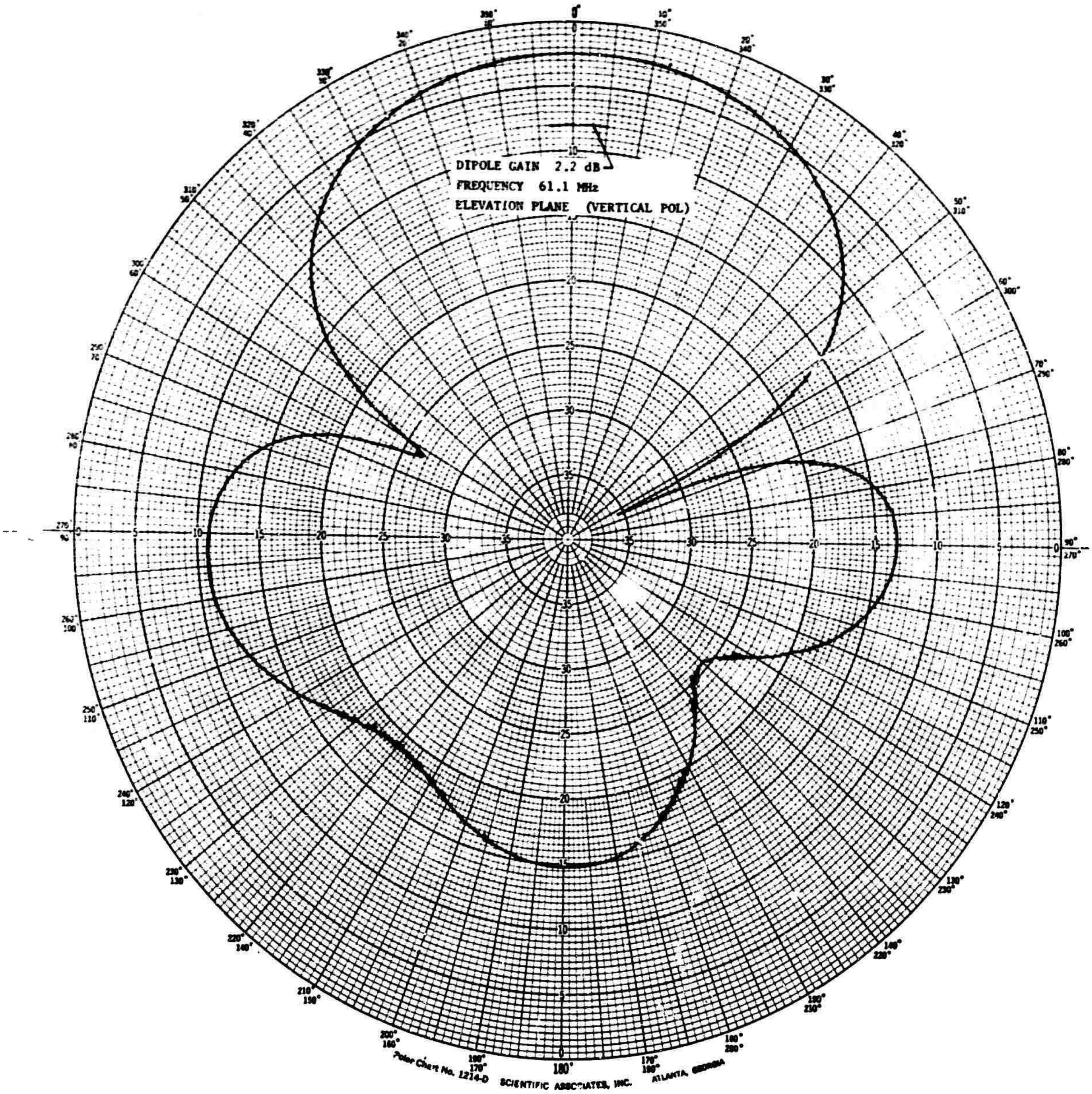

DIPOLE GAIN 2.2 dB
FREQUENCY 61.1 MHz
ELEVATION PLANE (VERTICAL POL)
Polar Chart No. 1214-D SCIENTIFIC ASSOCIATES, INC. ATLANTA, GEORGIA

Figure 26

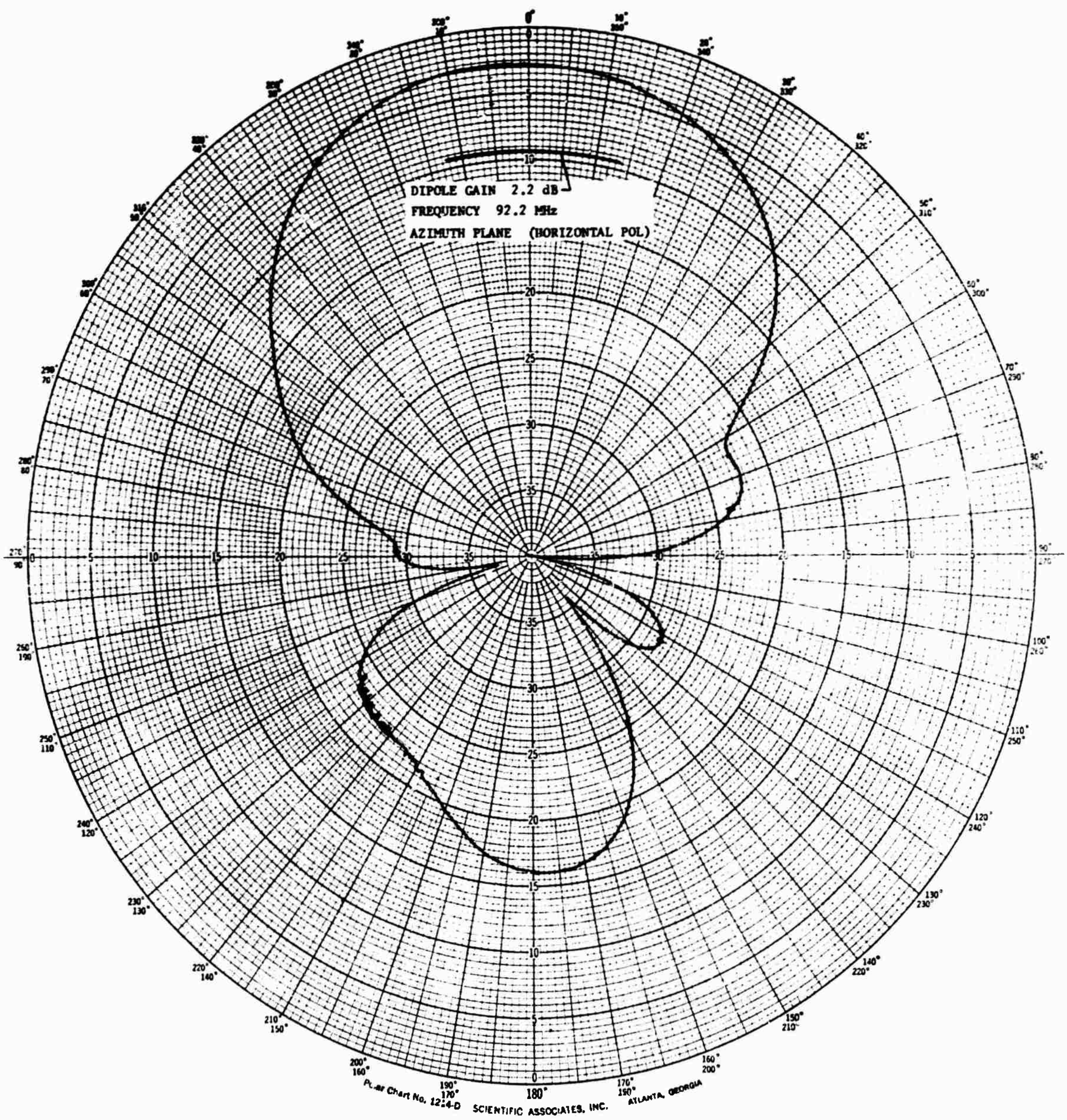

DIPOLE GAIN 2.2 dB
FREQUENCY 92.2 MHz
AZIMUTH PLANE (HORIZONTAL POL)
Polar Chart No. 1214-D SCIENTIFIC ASSOCIATES, INC. ATLANTA, GEORGIA

Figure 27

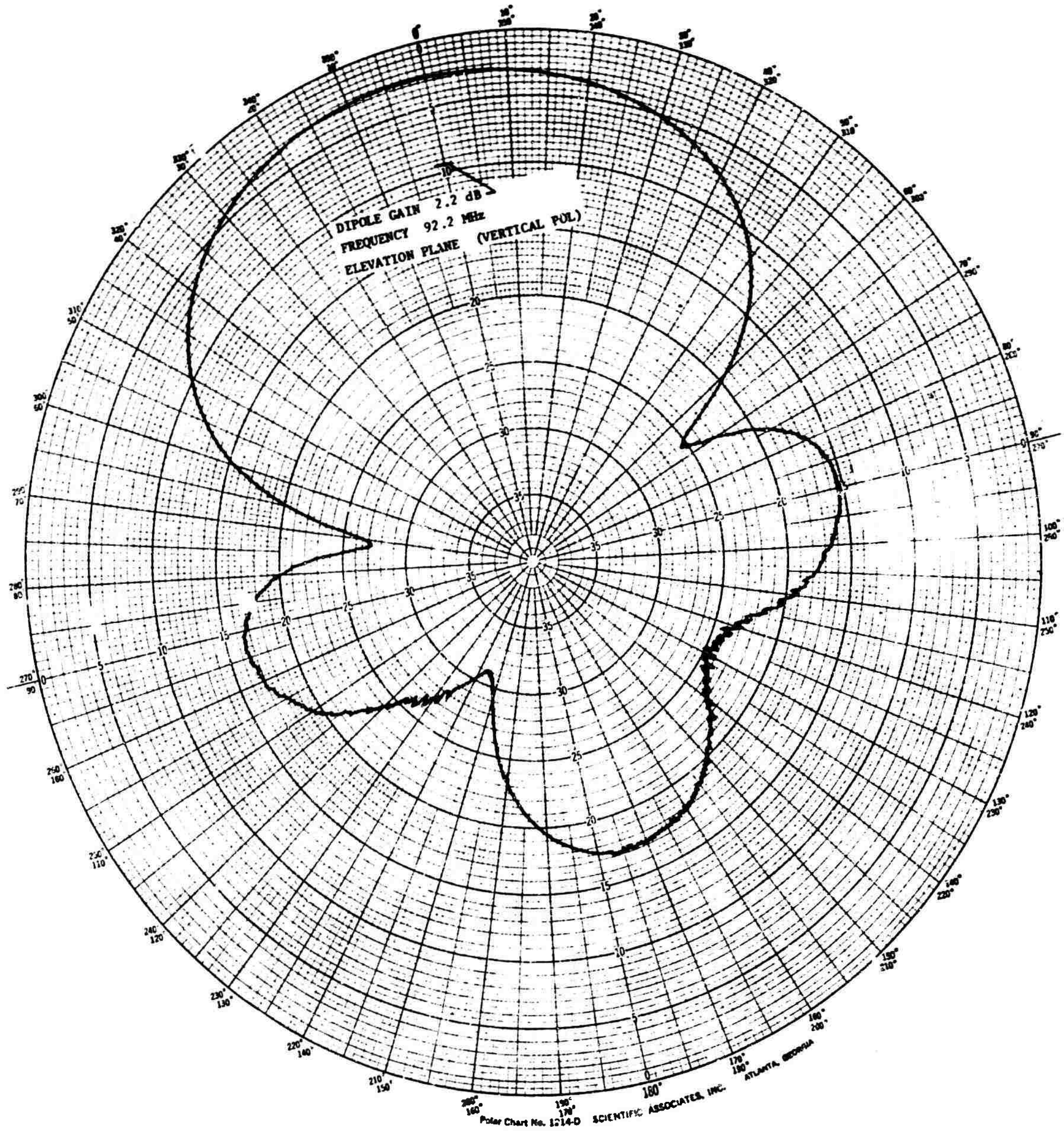

DIPOLE GAIN 2.2 dB
FREQUENCY 92.2 MHz
ELEVATION PLANE (VERTICAL POL)
Polar Chart No. 1214-D SCIENTIFIC ASSOCIATES, INC. ATLANTA, GEORGIA

Figure 28

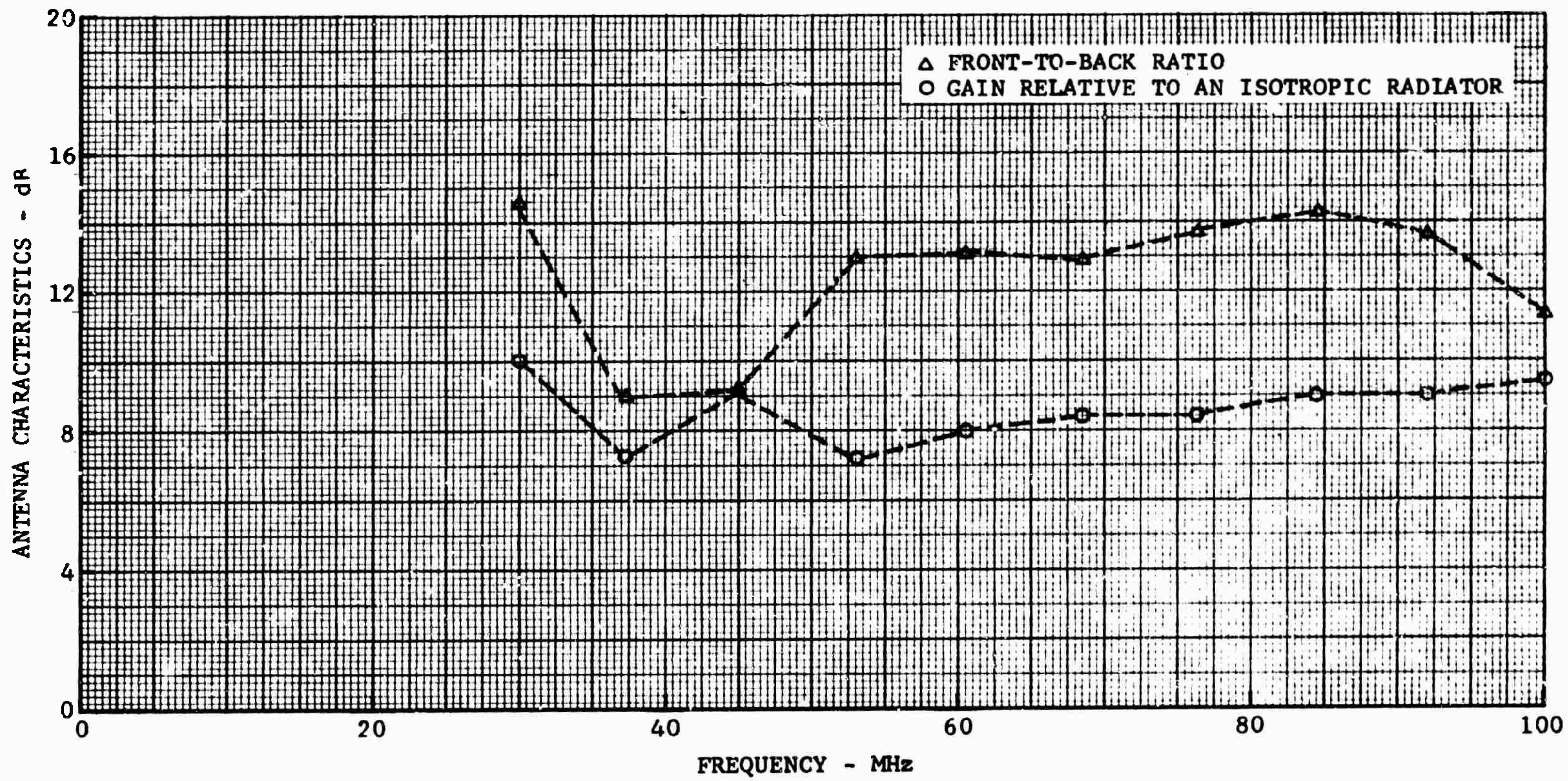


Figure 29. ANTENNA CHARACTERISTICS

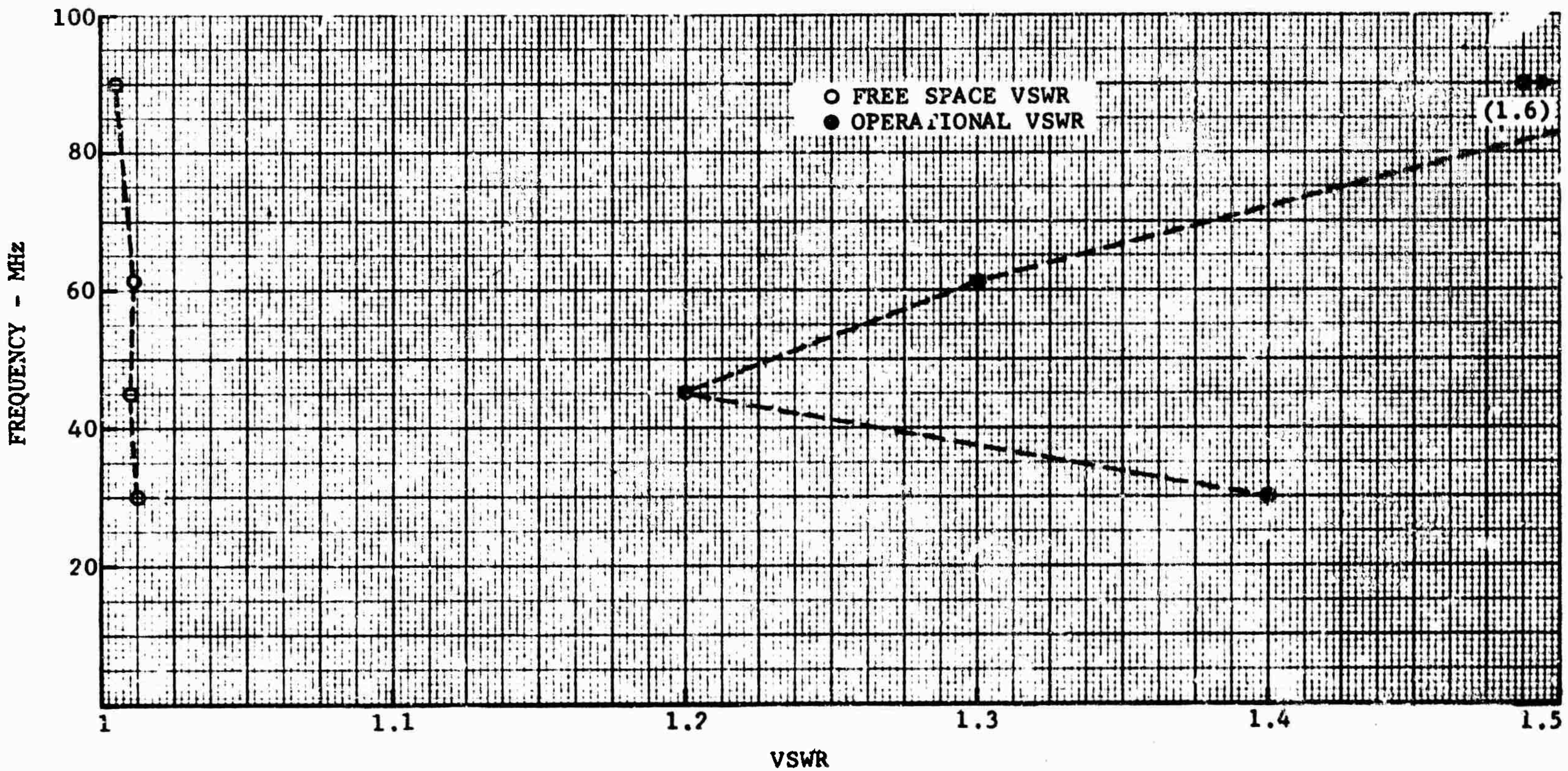


Figure 30. ANTENNA VSWR

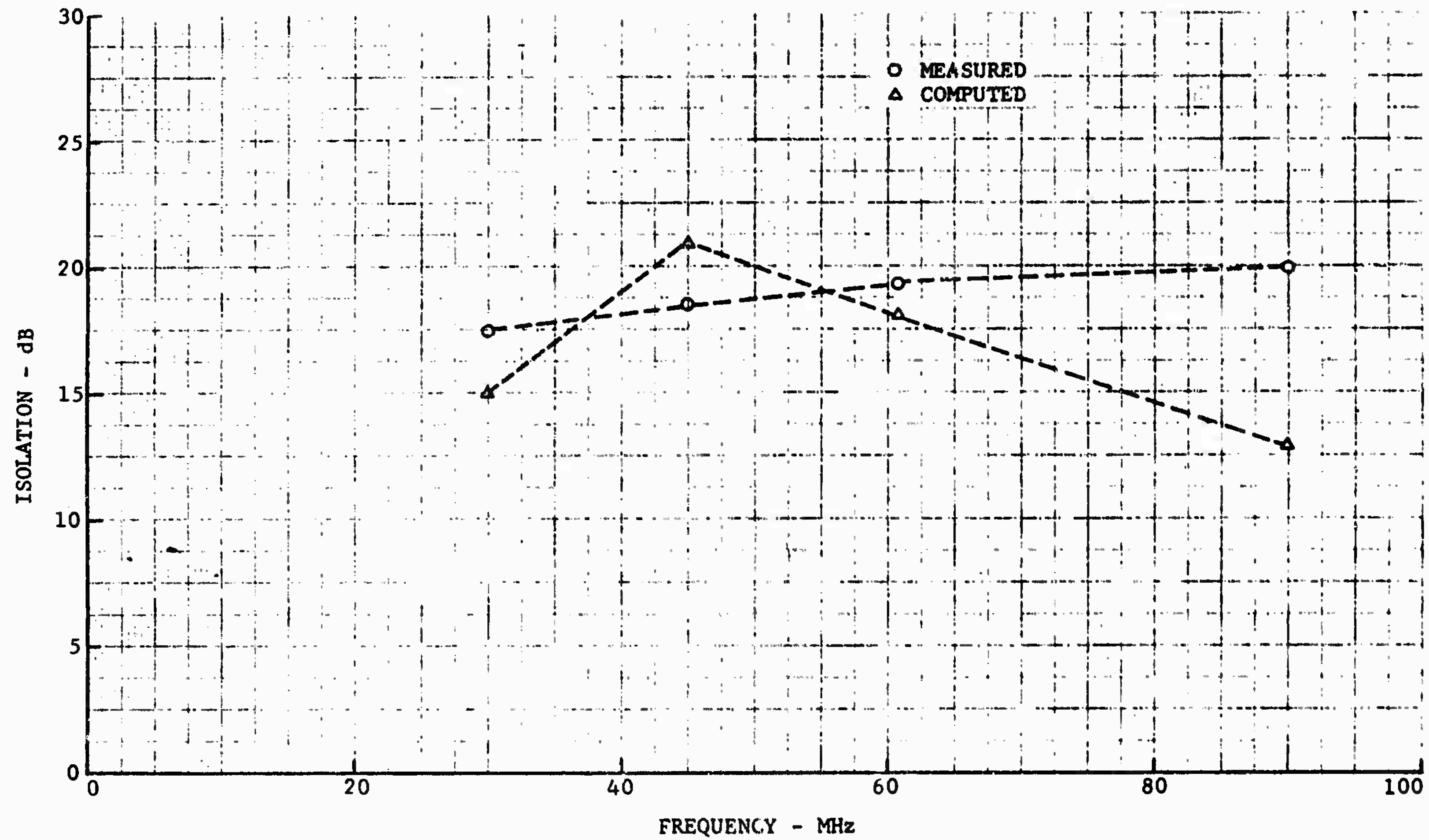


Figure 31. SINGLE ANTENNA HYBRID ISOLATION

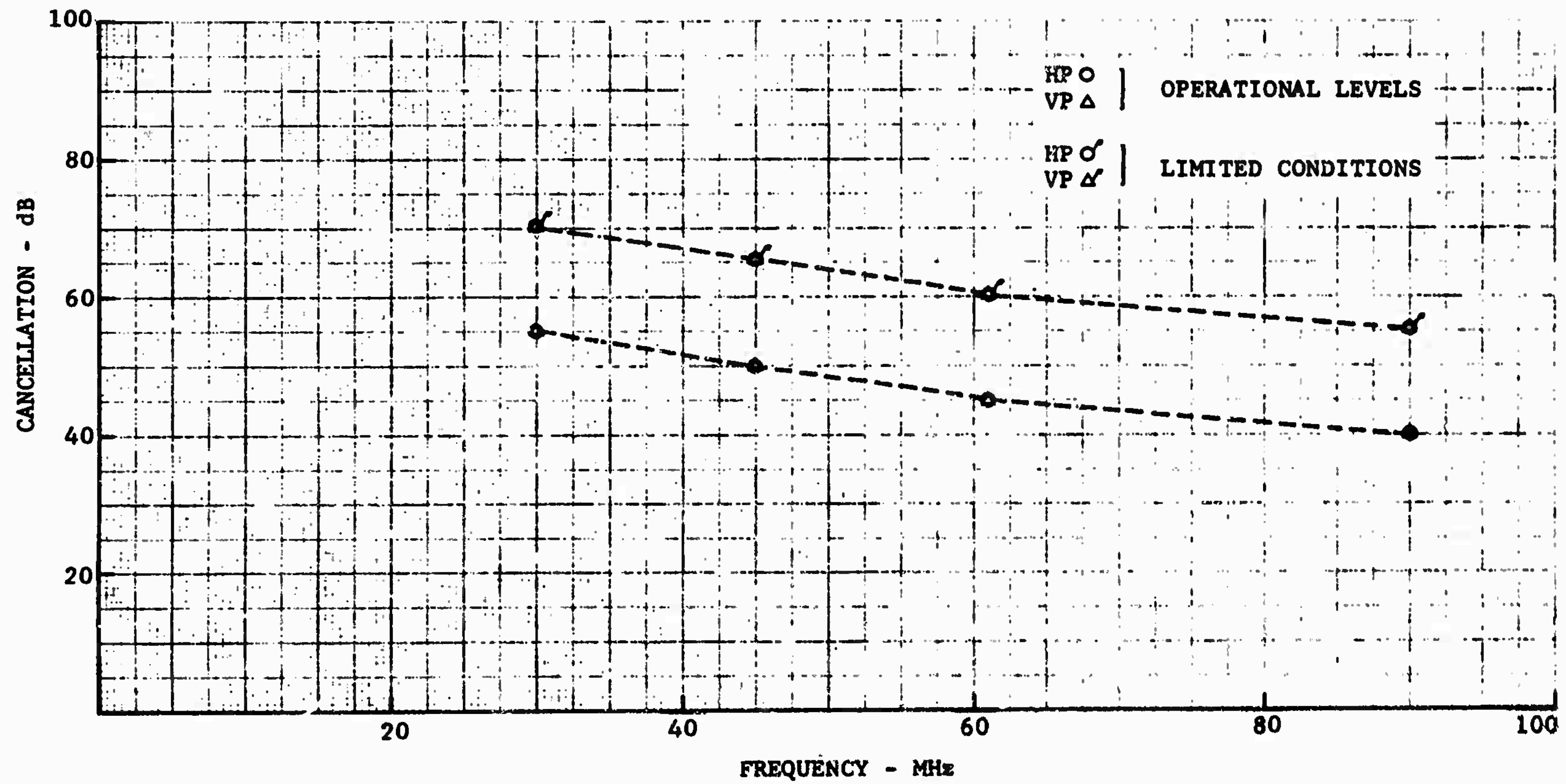


Figure 32. CANCELLATION STABILITY

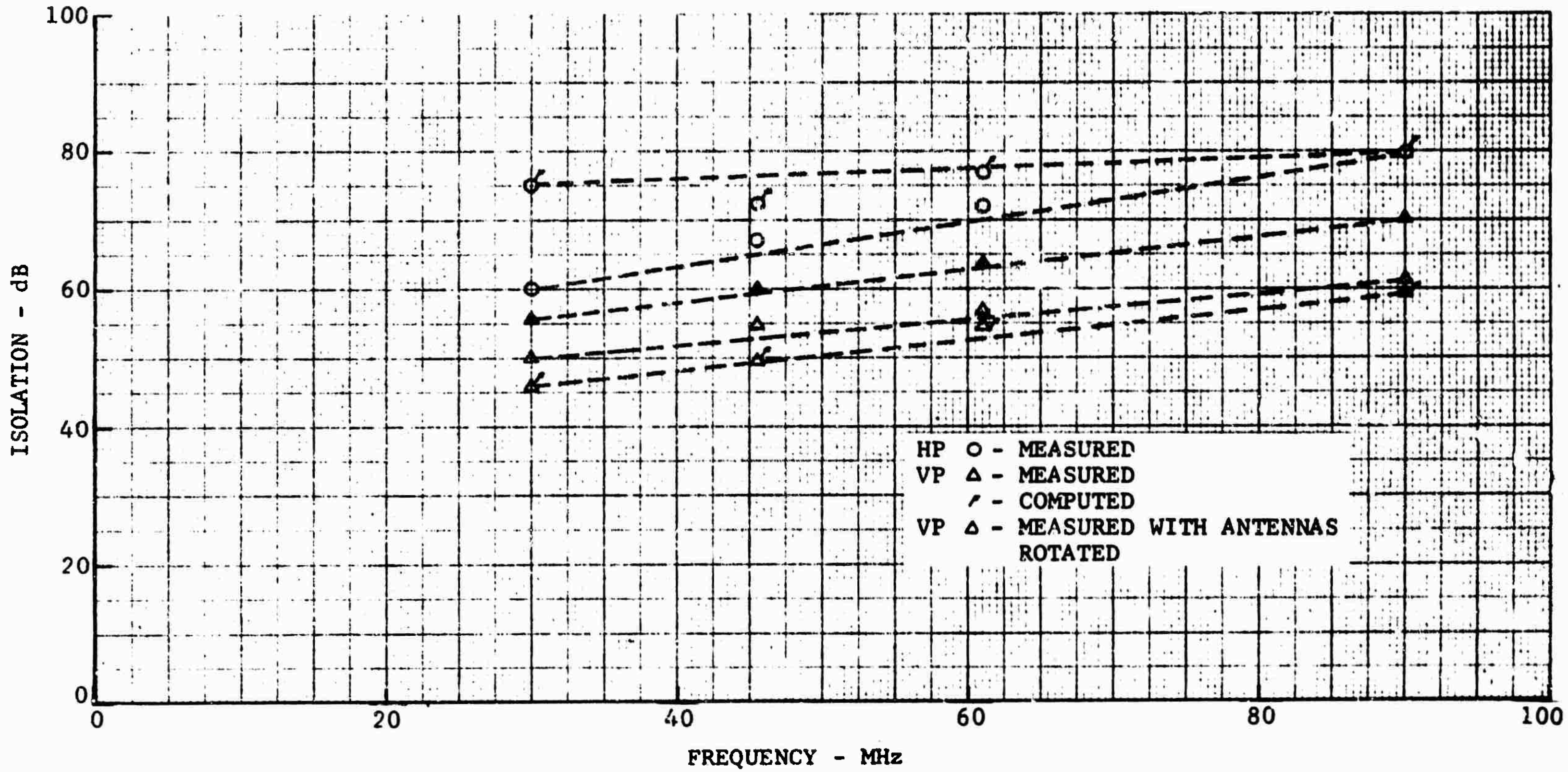


Figure 33. DUAL ANTENNA ISOLATION

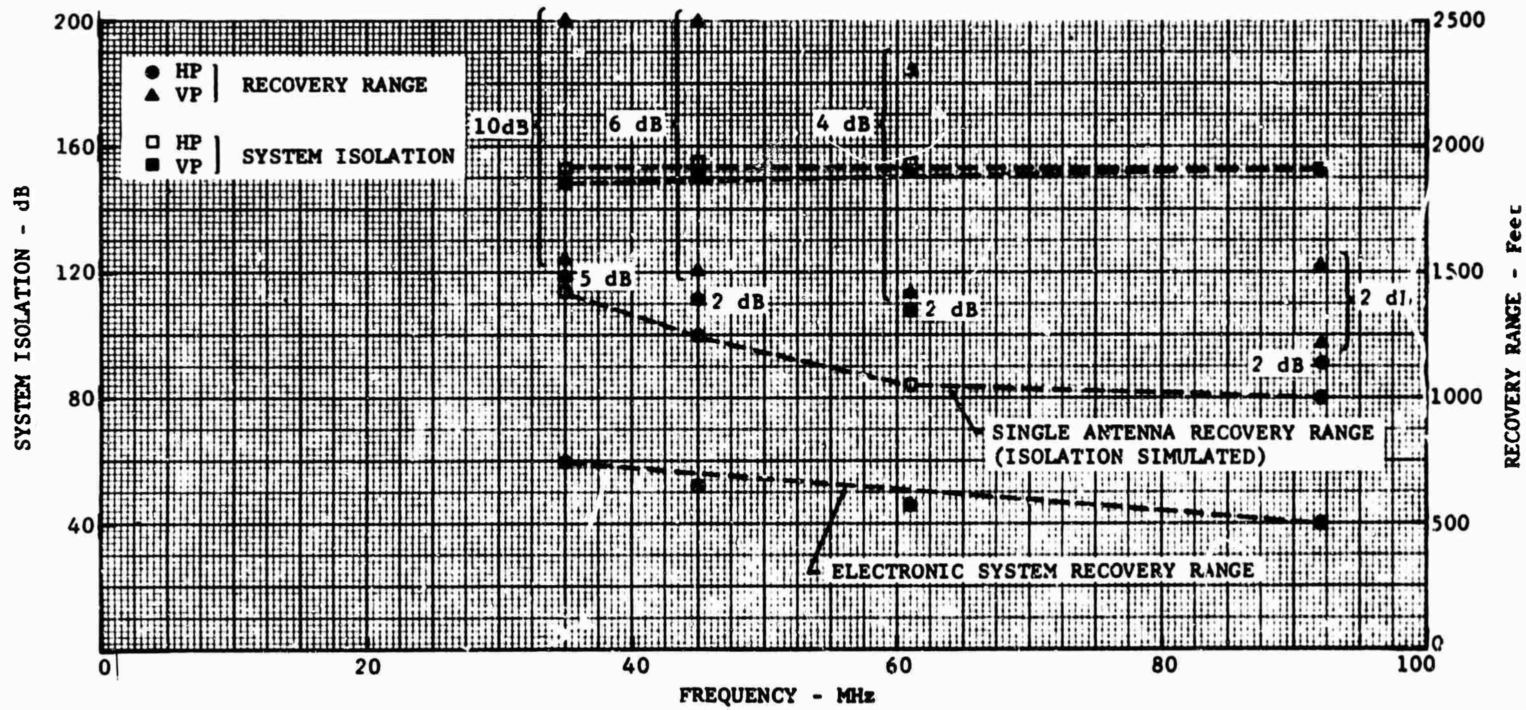


Figure 34. SYSTEM ISOLATION AND RECOVERY RANGE

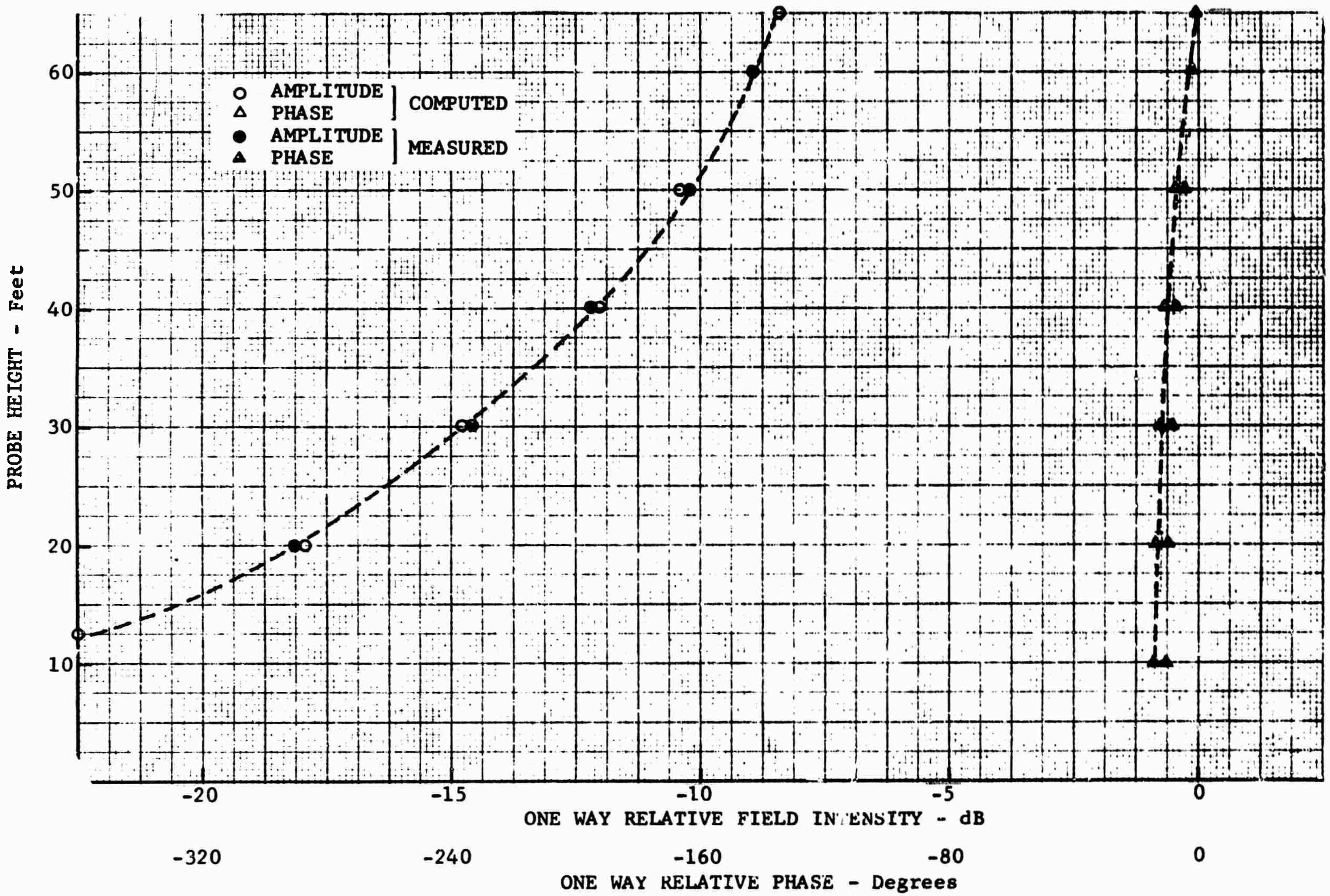


Figure 35. FIELD PROBE DATA (HORIZONTAL POL - 30 MHz)

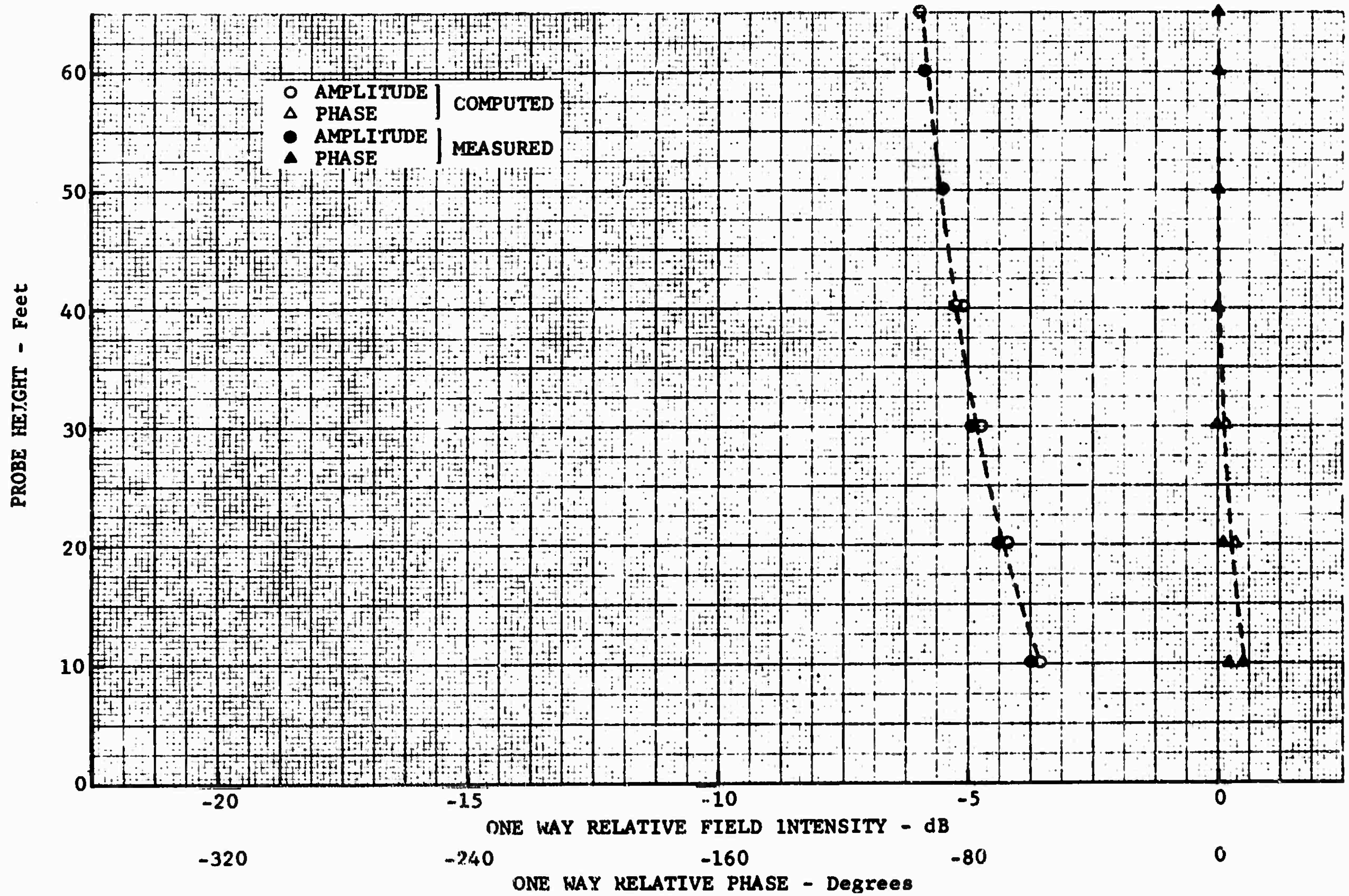


Figure 36. FIELD PROBE DATA (VERTICAL POL - 30 MHz)

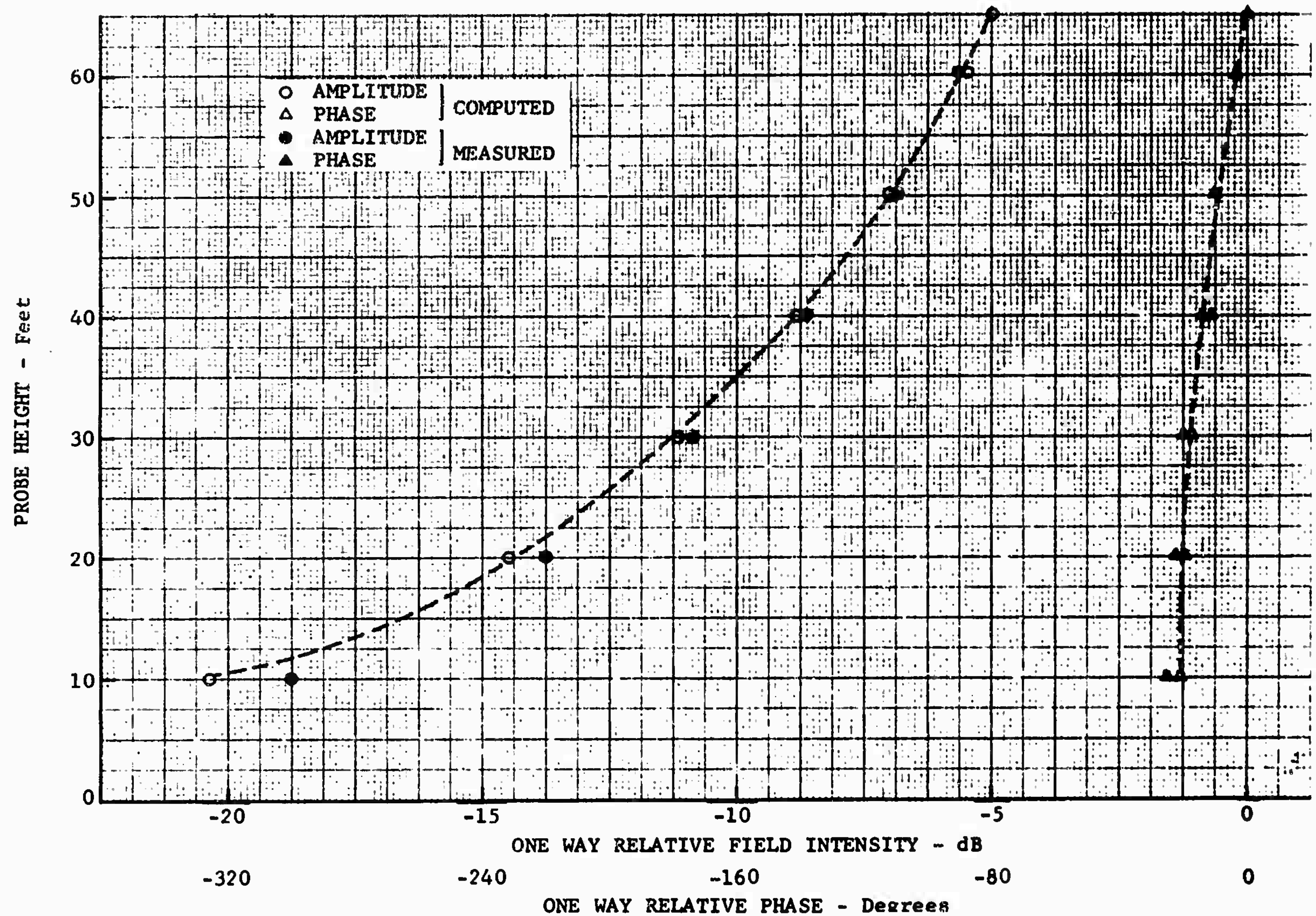


Figure 37. FIELD PROBE DATA (HORIZONTAL POL - 45.5 MHz)

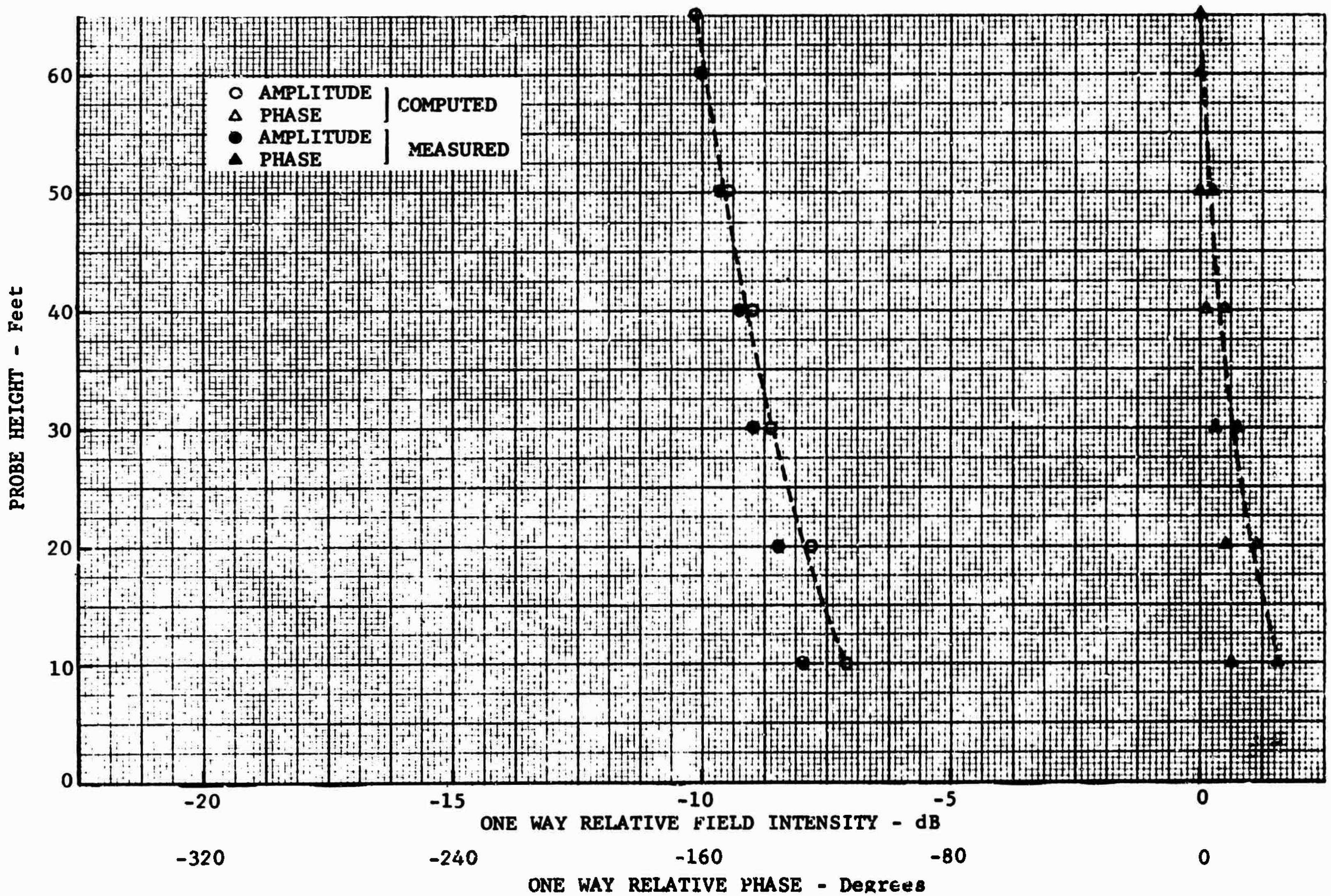


Figure 38. FIELD PROBE DATA (VERTICAL POL - 45.5 MHz)

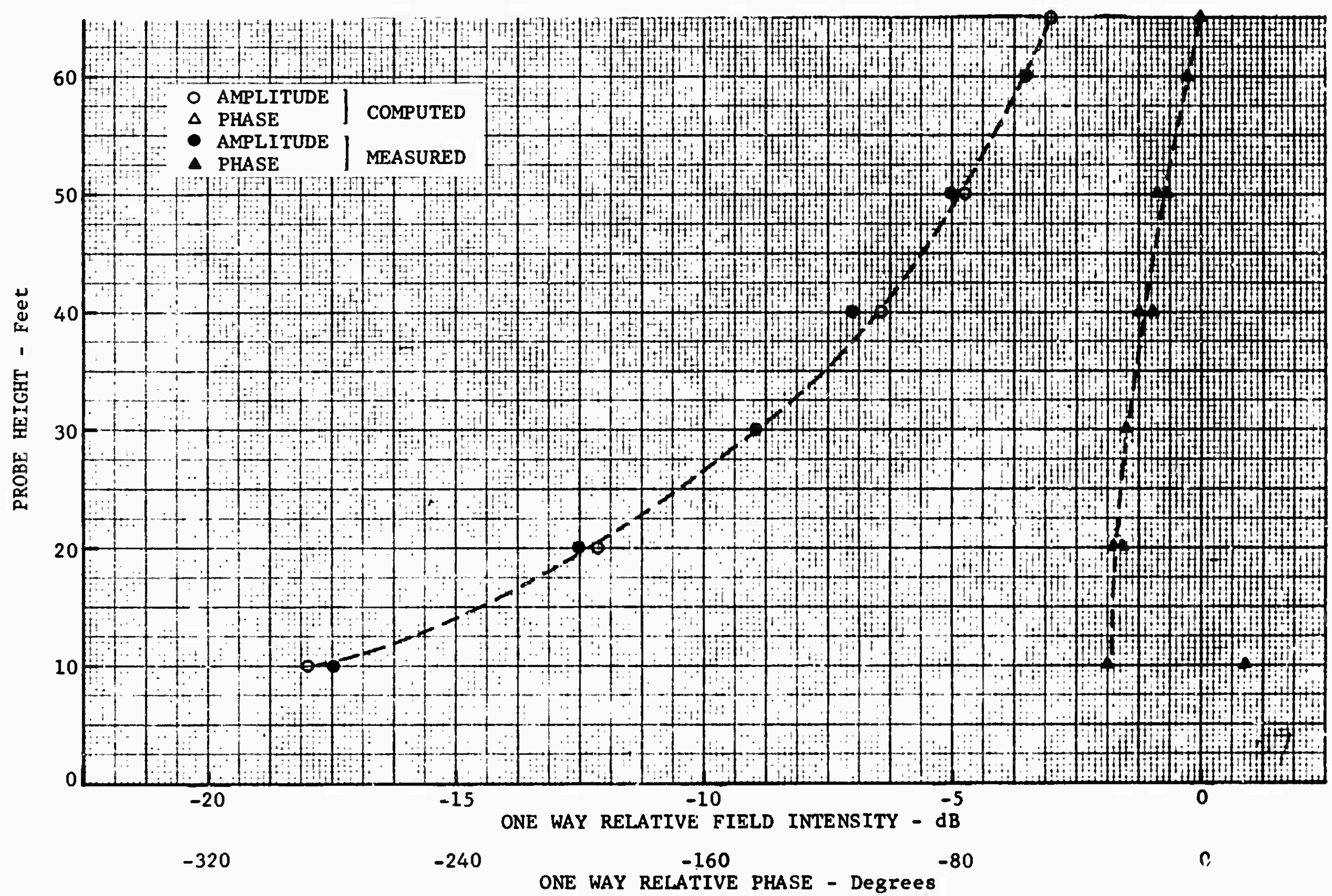


Figure 39. FIELD PROBE DATA (HORIZONTAL POL - 61.1 MHz)

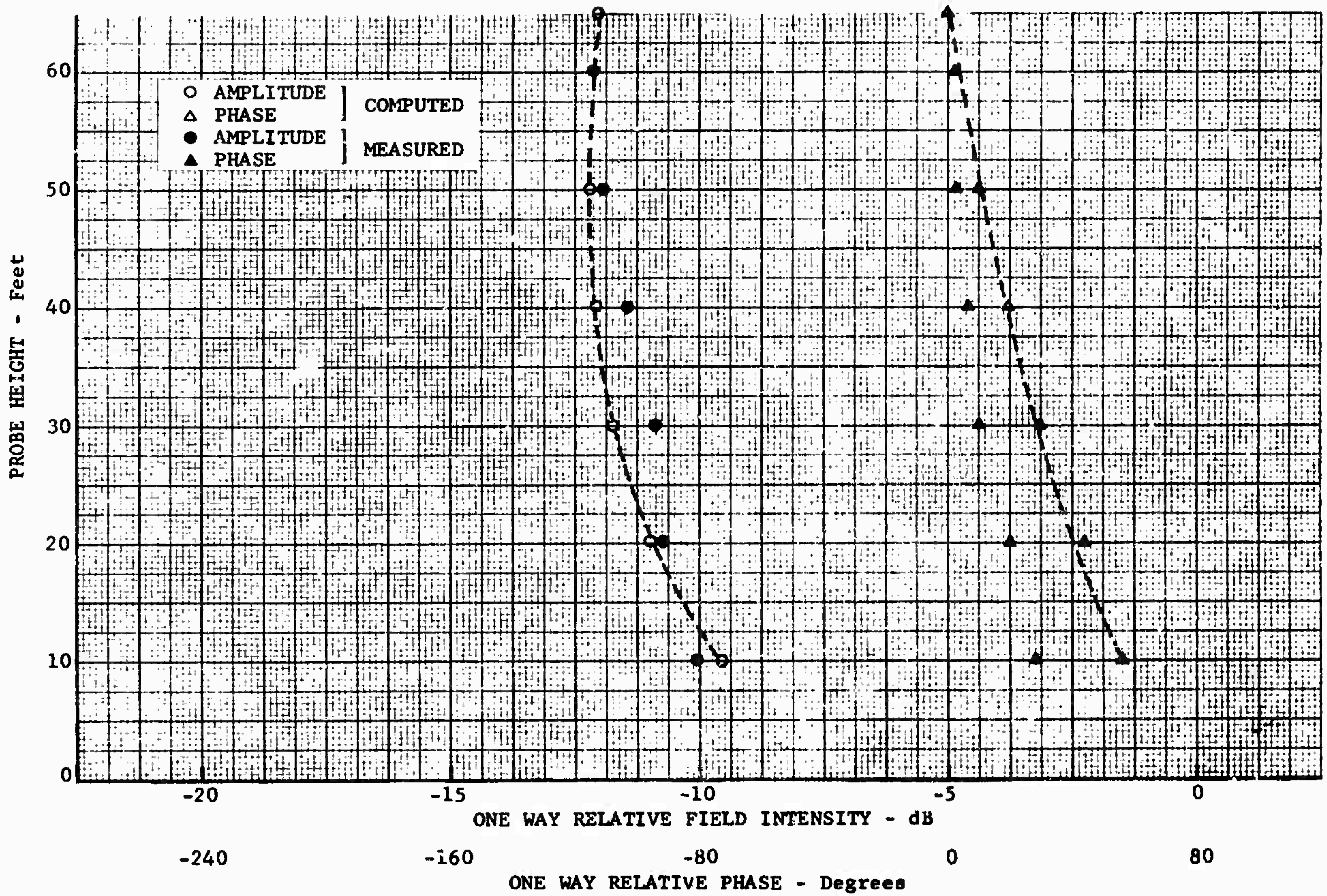


Figure 40. FIELD PROBE DATA (VERTICAL POL - 61.1)

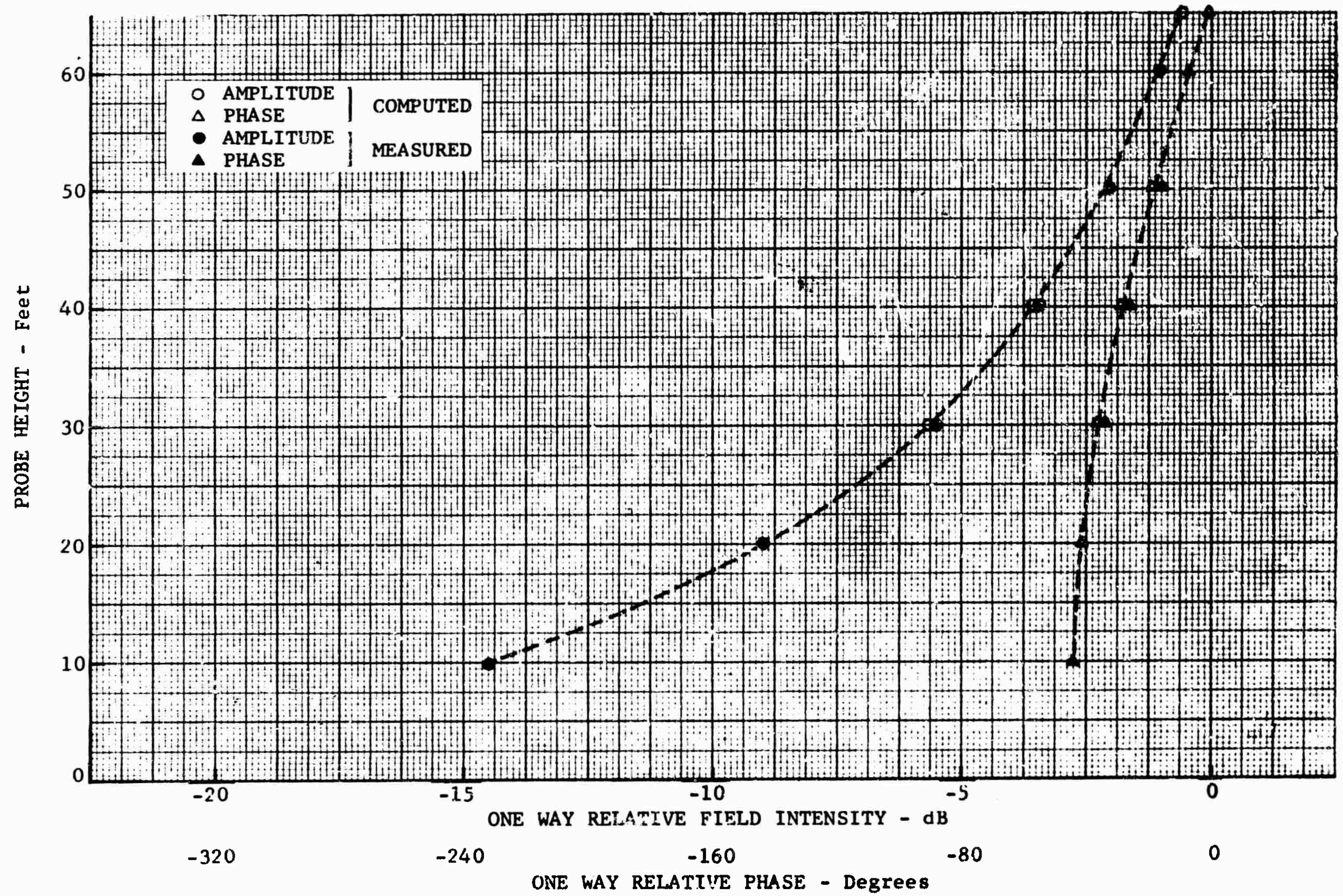


Figure 41. FIELD PROBE DATA (HORIZONTAL POL - 92.2 MHz)

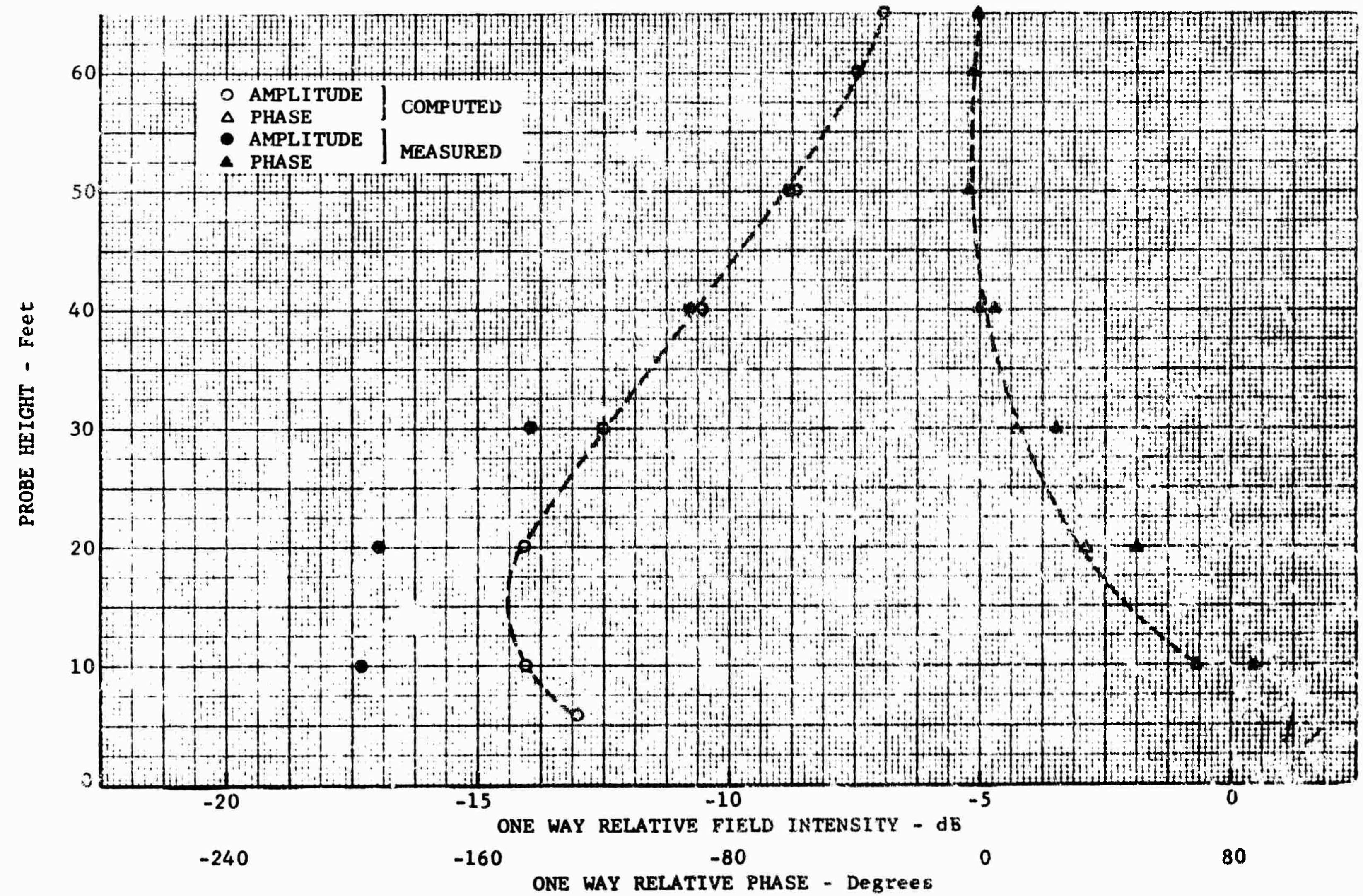
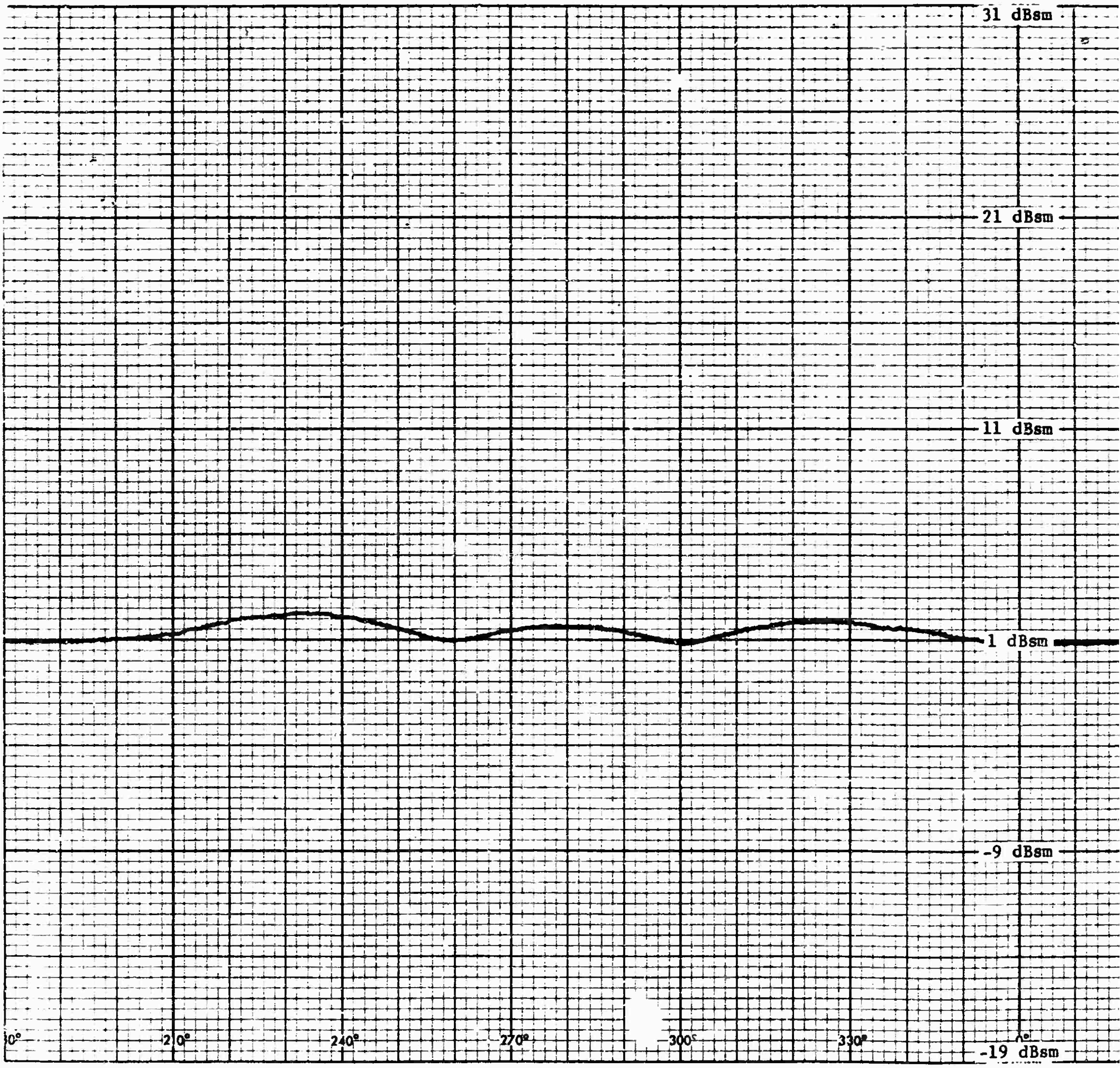


Figure 42. FIELD PROBE DATA (VERTICAL POL - 92.2 MHz)



31 dBsm
21 dBsm
11 dBsm
1 dBsm
-9 dBsm
-19 dBsm
210°
240°
270°
300°
330°
0°

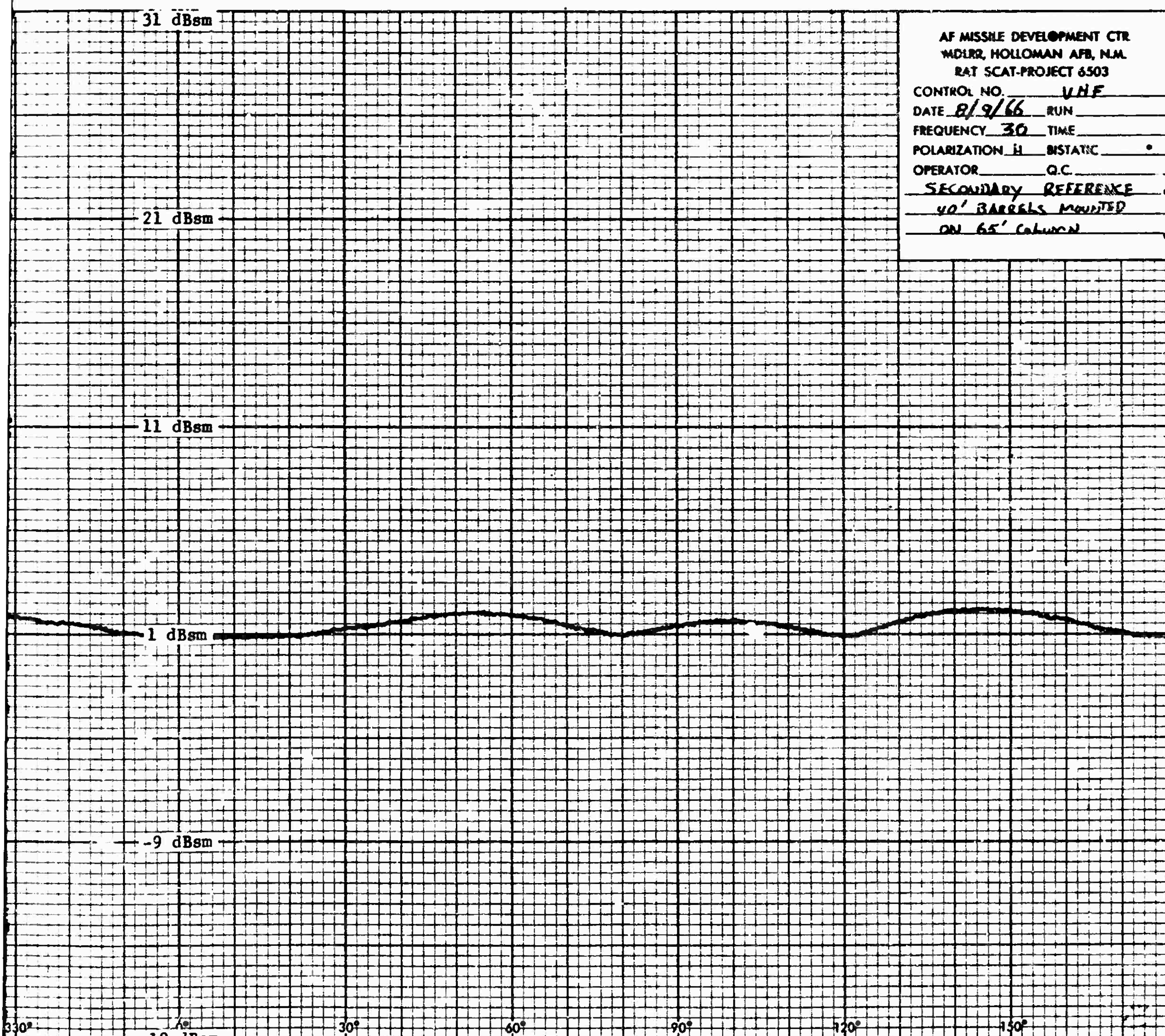

31 dBsm
21 dBsm
11 dBsm
1 dBsm
-9 dBsm
-19 dBsm
330°
0°
30°
60°
90°
120°
150°
AF MISSILE DEVELOPMENT CTR
MDLRR, HOLLOMAN AFB, N.M.
RAT SCAT-PROJECT 6503
CONTROL NO. VHF
DATE 8/9/66 RUN
FREQUENCY 30 TIME
POLARIZATION H BISTATIC
OPERATOR Q.C.
SECONDARY REFERENCE
40' BARRELS MOUNTED
ON 65' COLUMN

Figure 43

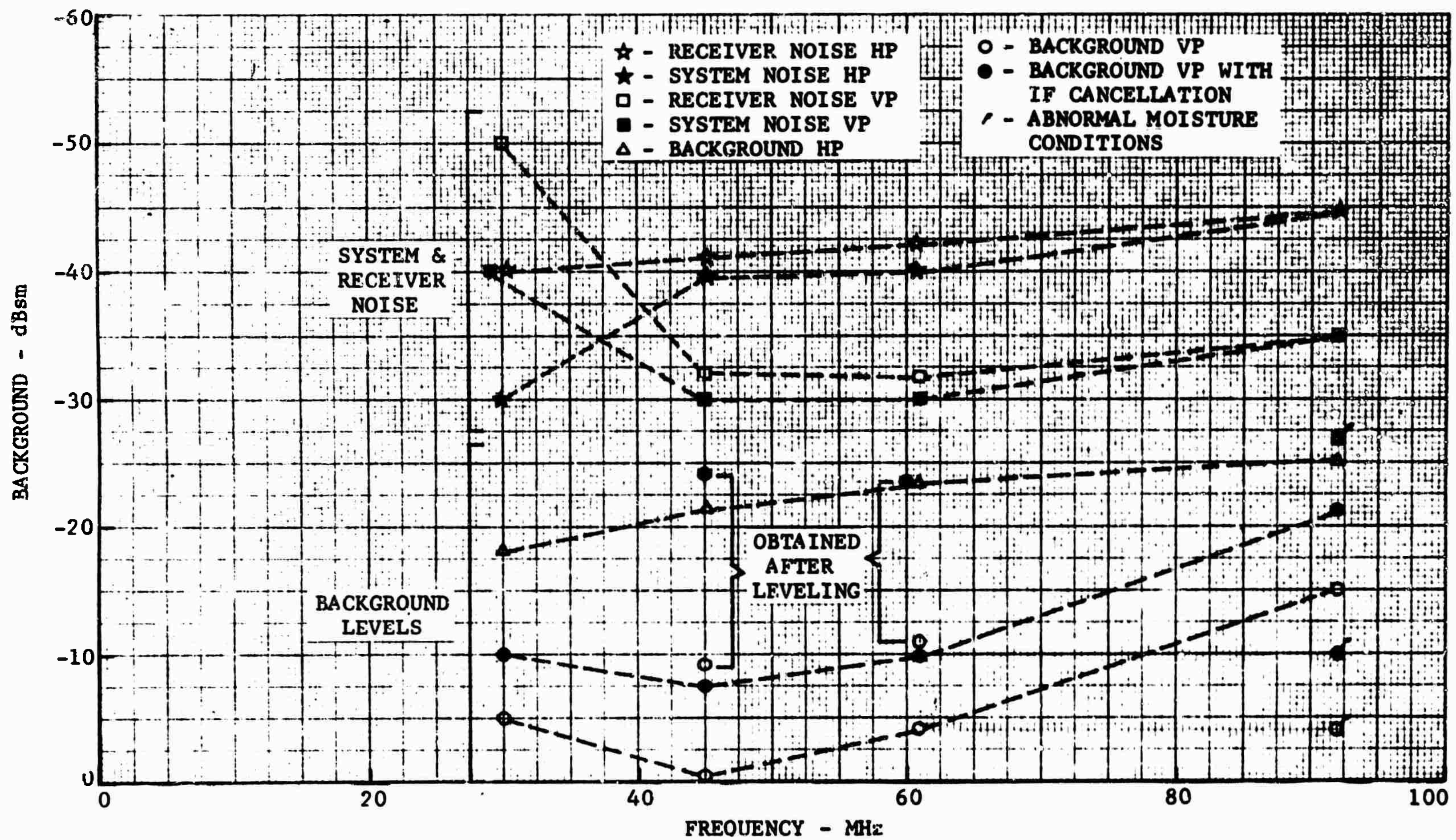
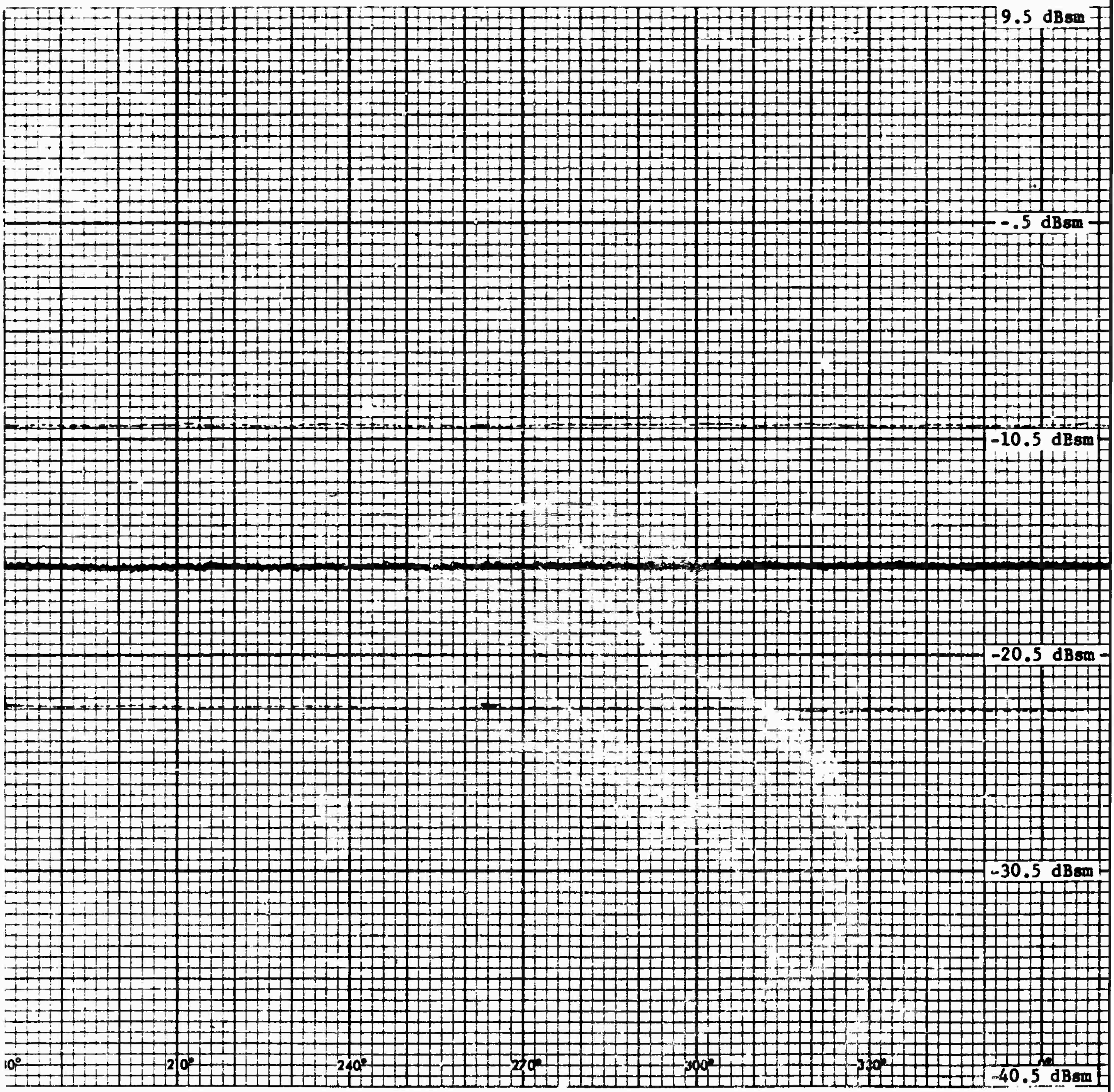


Figure 44. BACKGROUND LEVELS


9.5 dBsm
-.5 dBsm
-10.5 dBsm
-20.5 dBsm
-30.5 dBsm
-40.5 dBsm
210°
240°
270°
300°
330°

1

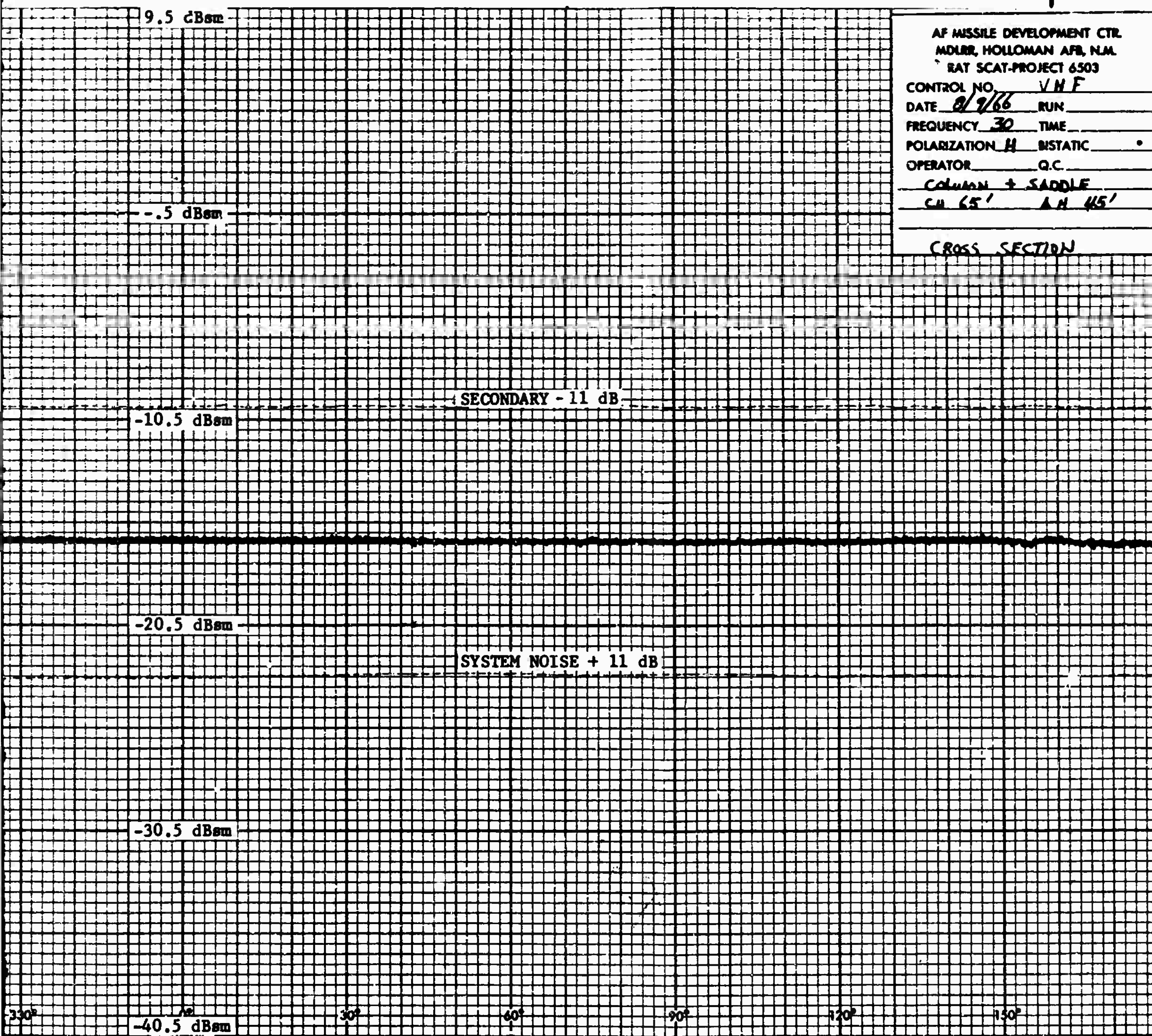
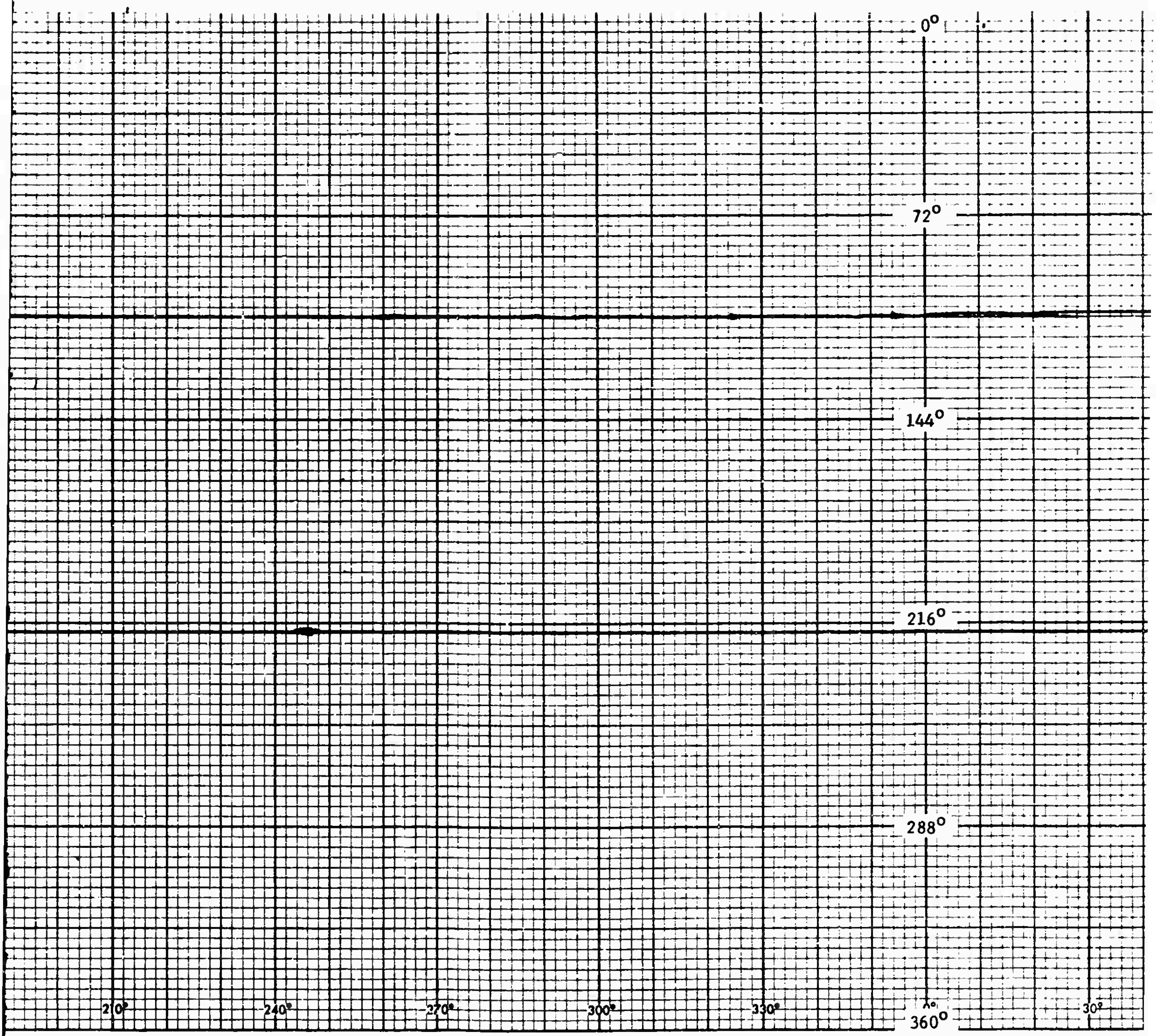
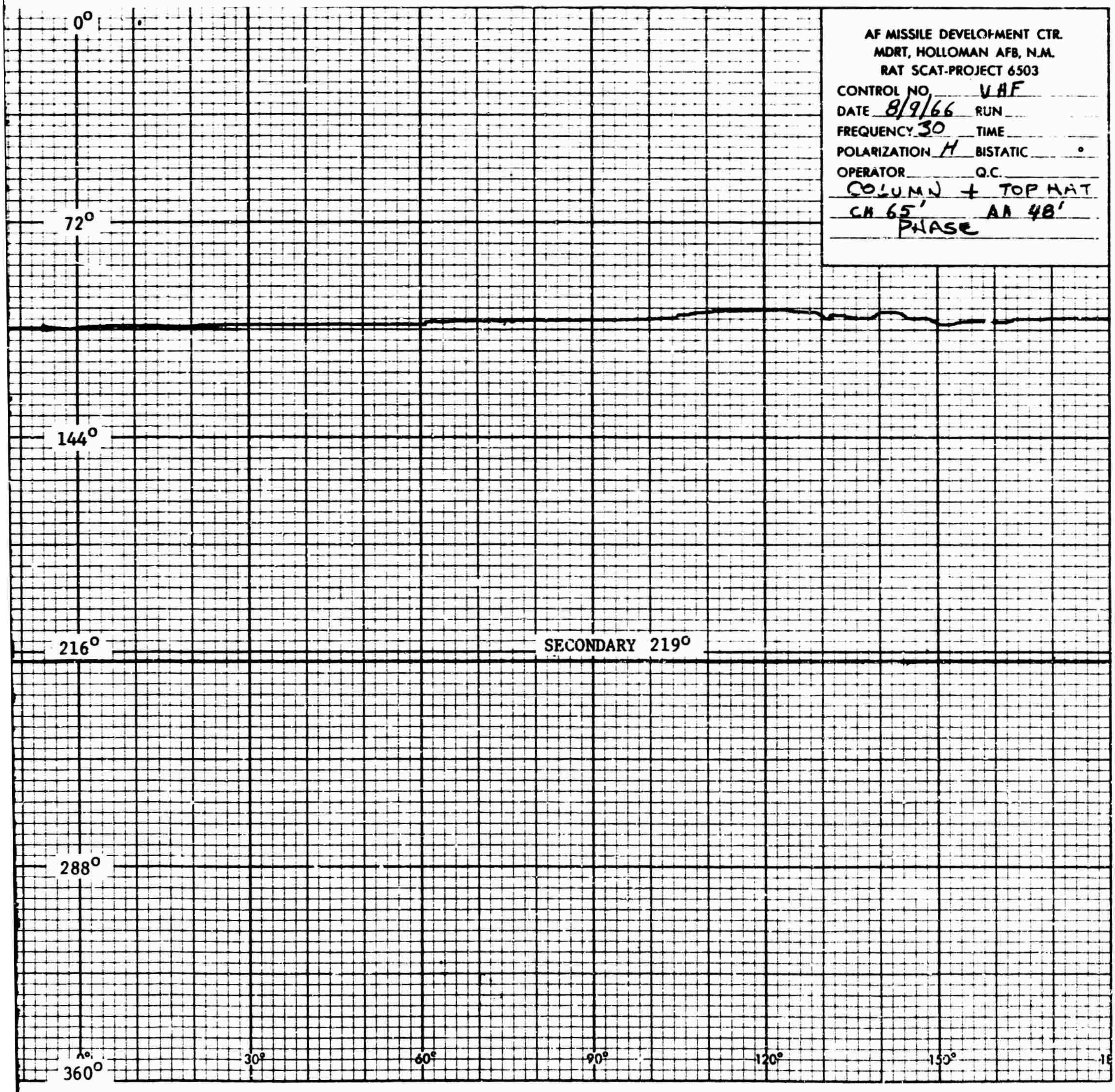

9.5 dBsm
-.5 dBsm
SECONDARY - 11 dB
-10.5 dBsm
-20.5 dBsm
SYSTEM NOISE + 11 dB
-30.5 dBsm
-40.5 dBsm
330°
0°
30°
60°
90°
120°
150°
AF MISSILE DEVELOPMENT CTR.
MDLRR, HOLLOMAN AFB, N.M.
RAT SCAT-PROJECT 6503
CONTROL NO. VHF
DATE 8/9/66 RUN
FREQUENCY 30 TIME
POLARIZATION H BISTATIC
OPERATOR Q.C.
COLUMN + SADDLE
CH 65' AH 45'
CROSS SECTION

Figure 4

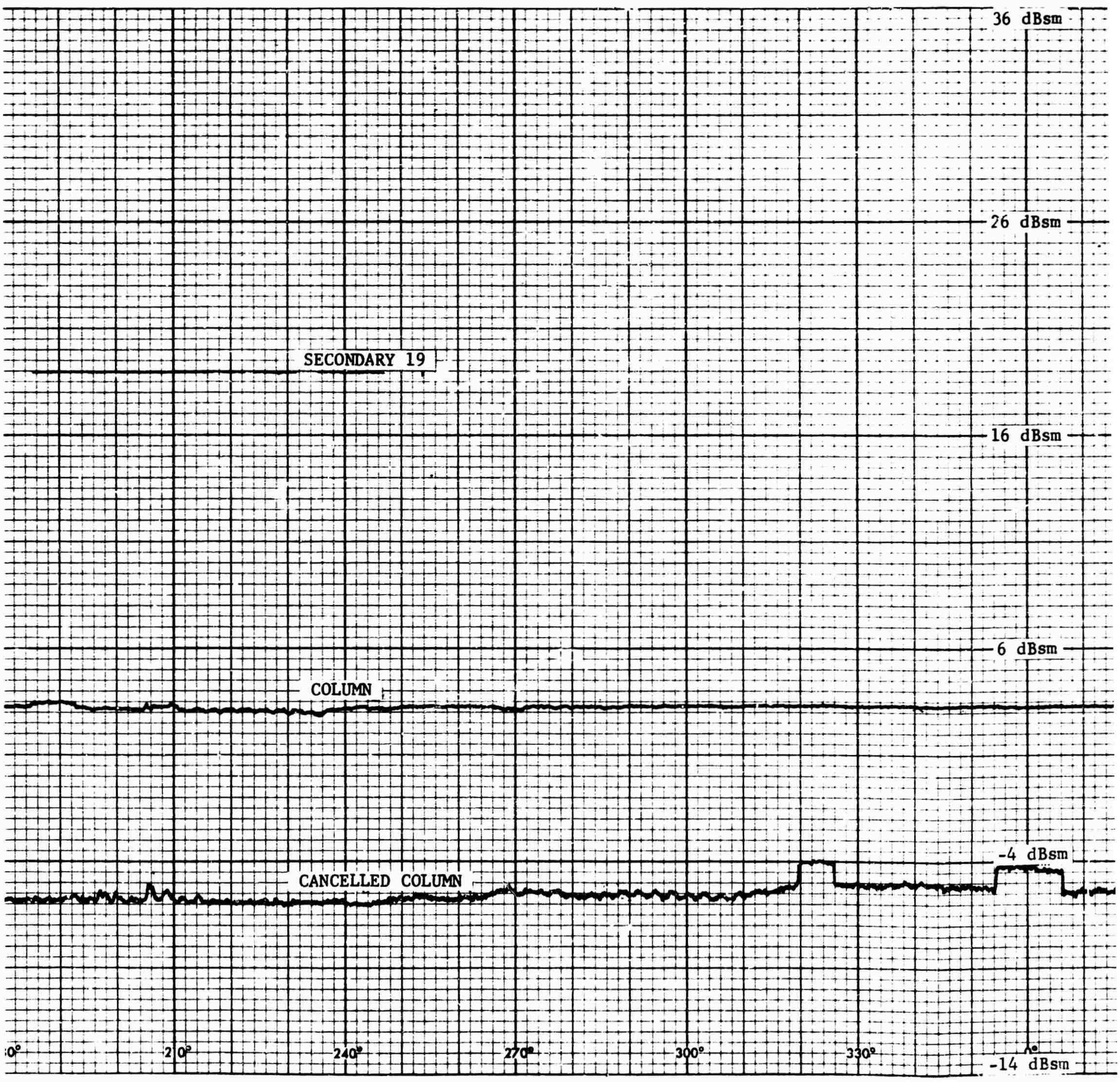


e 46

)4


AF MISSILE DEVELOPMENT CTR.
MDRT, HOLLOMAN AFB, N.M.
RAT SCAT-PROJECT 6503
CONTROL NO. VHF
DATE 8/9/66 RUN
FREQUENCY 30 TIME
POLARIZATION H BISTATIC °
OPERATOR Q.C.
COLUMN + TOP HAT
CH 65' AH 48'
PHASE
0°
72°
144°
216°
SECONDARY 219°
288°
360°
30°
60°
90°
120°
150°

2


36 dBsm
26 dBsm
SECONDARY 19
16 dBsm
6 dBsm
COLUMN
-4 dBsm
CANCELLED COLUMN
240°
270°
300°
330°
-14 dBsm

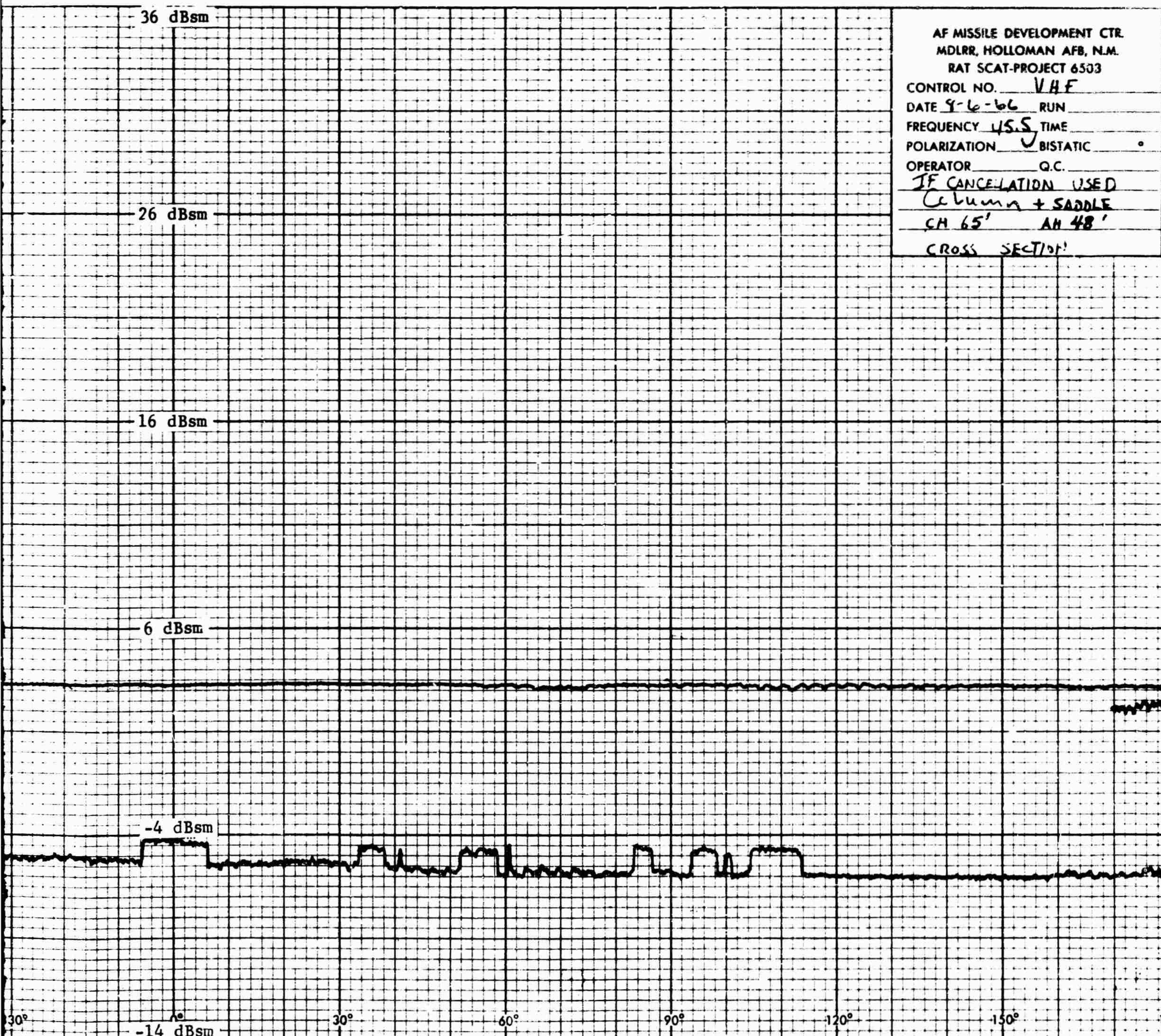

36 dBsm
26 dBsm
16 dBsm
6 dBsm
-4 dBsm
-14 dBsm
30°
0°
30°
60°
90°
120°
150°
AF MISSILE DEVELOPMENT CTR.
MDLRR, HOLLOMAN AFB, N.M.
RAT SCAT-PROJECT 6503
CONTROL NO. VHF
DATE 9-6-66 RUN
FREQUENCY 45.5 TIME
POLARIZATION V BISTATIC °
OPERATOR Q.C.
IF CANCELATION USED
Column + SADDLE
CH 65' AH 48'
CROSS SECTION

Figure 47

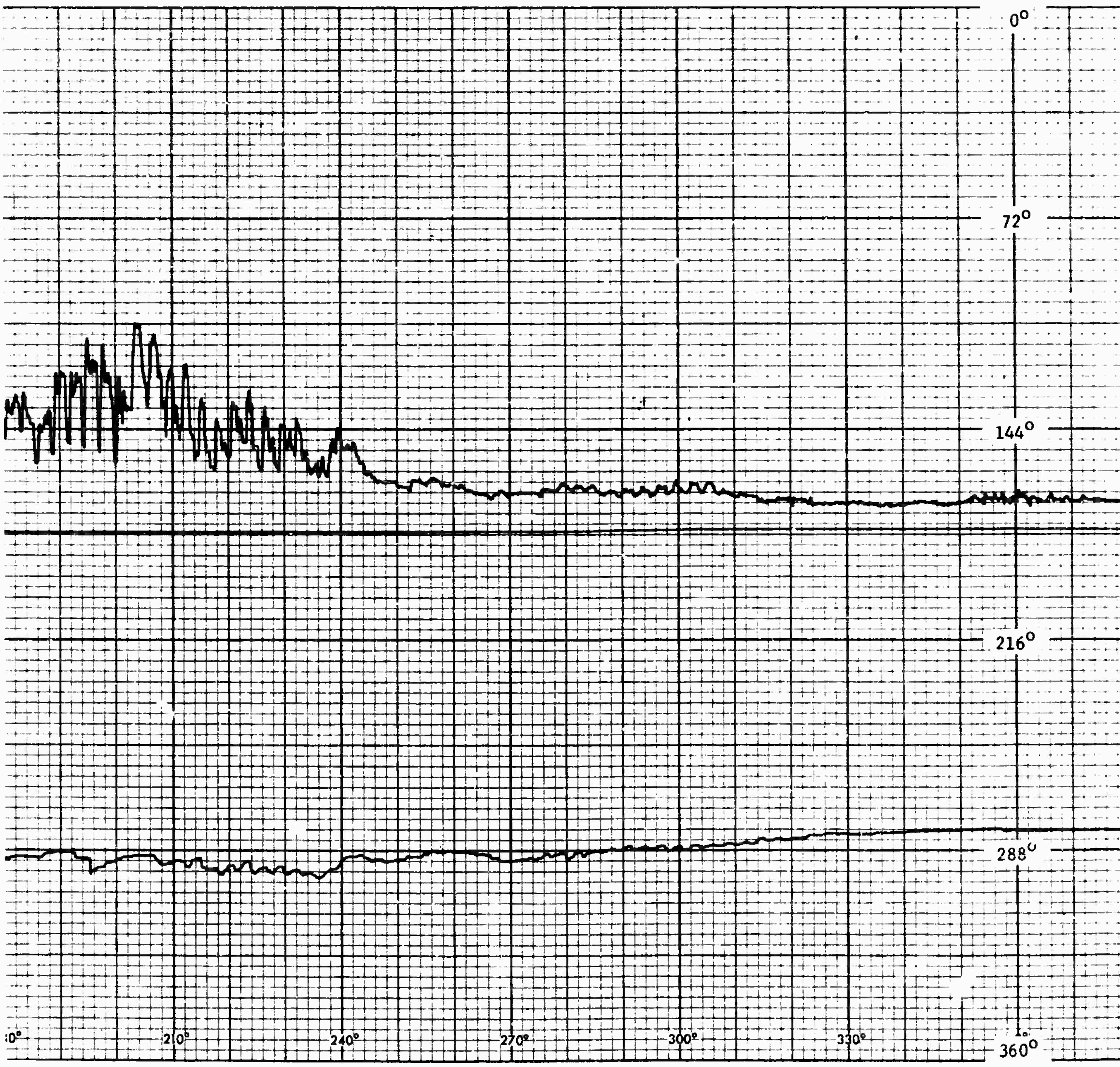
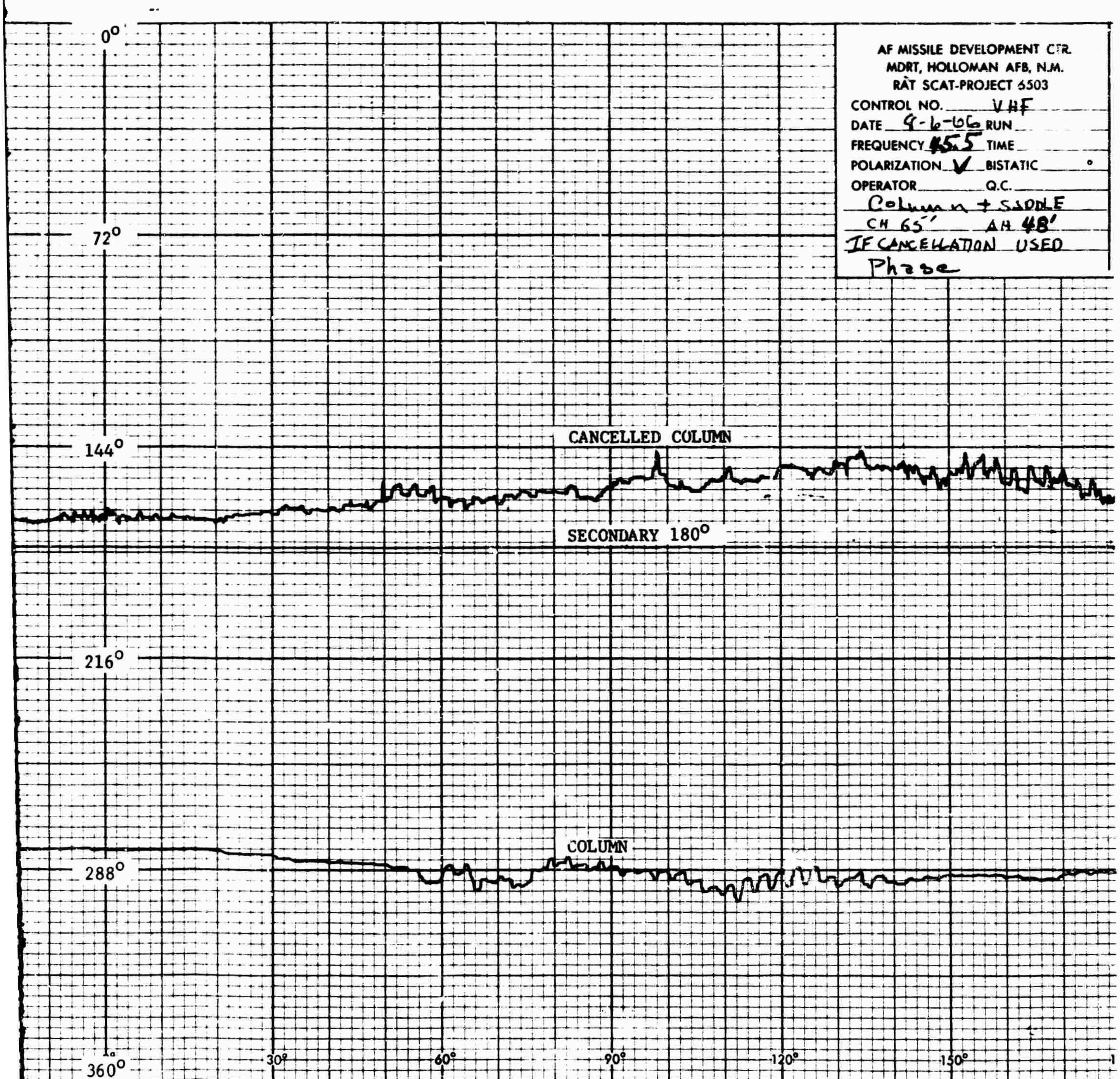
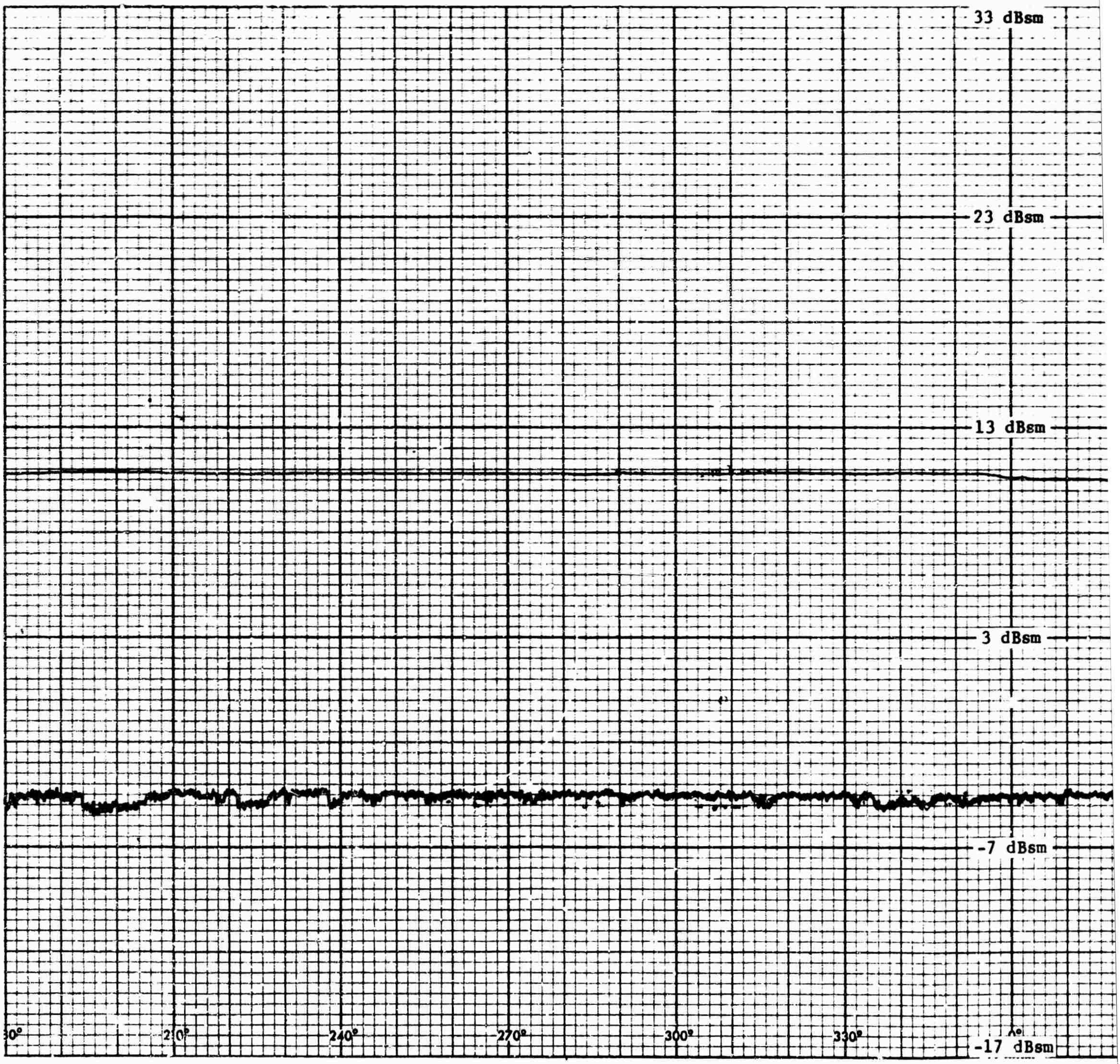


Figure 48

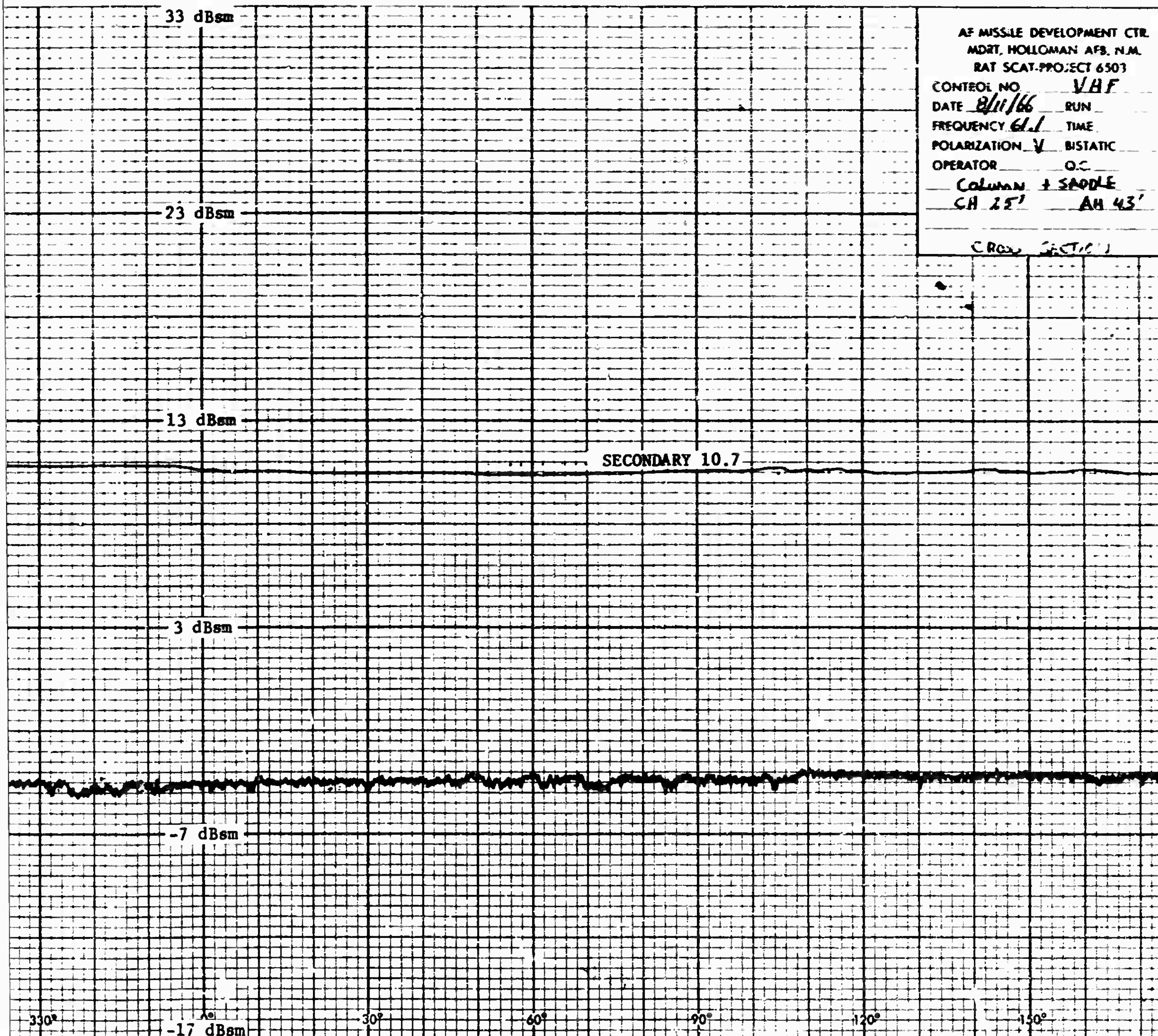
1


AF MISSILE DEVELOPMENT CTR.
MDRT, HOLLOMAN AFB, N.M.
RAT SCAT-PROJECT 6503
CONTROL NO. VHF
DATE 9-6-66 RUN
FREQUENCY TIME
POLARIZATION V BISTATIC °
OPERATOR Q.C.
Column + SADDLE
CH 65' AH 48'
IF CANCELLATION USED
Phase
0°
72°
144°
216°
288°
360°
30°
60°
90°
120°
150°
CANCELLED COLUMN
SECONDARY 180°
COLUMN

2



1



AF MISSILE DEVELOPMENT CTR.
MDRT, HOLLOMAN AFB, N.M.
RAT SCAT-PROJECT 6503
CONTROL NO. VHF
DATE 8/11/66 RUN
FREQUENCY 61.1 TIME
POLARIZATION V BISTATIC
OPERATOR O.C.
COLUMN + SADDLE
CH 25' AH 43'
CROSS SECTION
33 dBsm
23 dBsm
13 dBsm
SECONDARY 10.7
3 dBsm
-7 dBsm
-17 dBsm
330°
30°
60°
90°
120°
150°

Figure

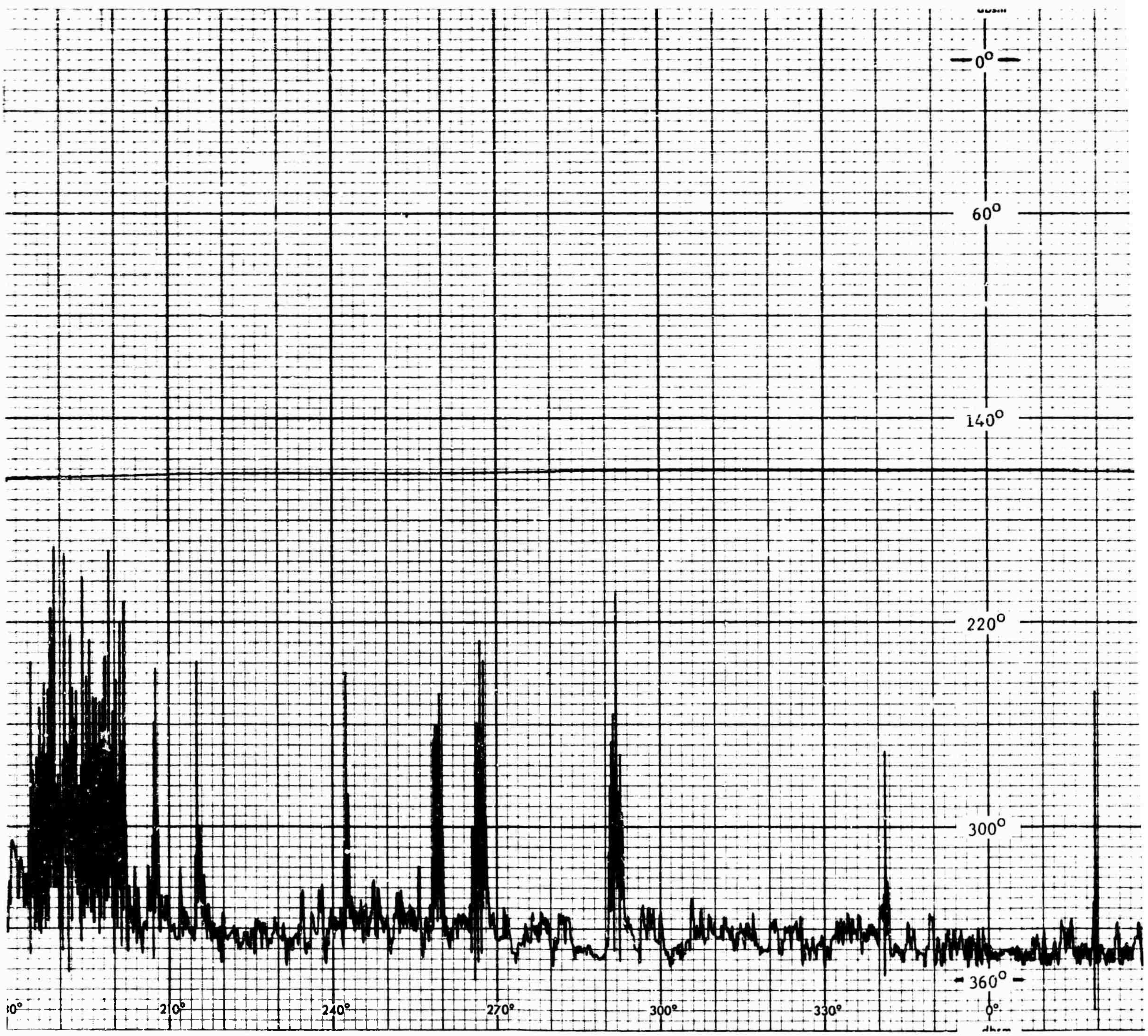
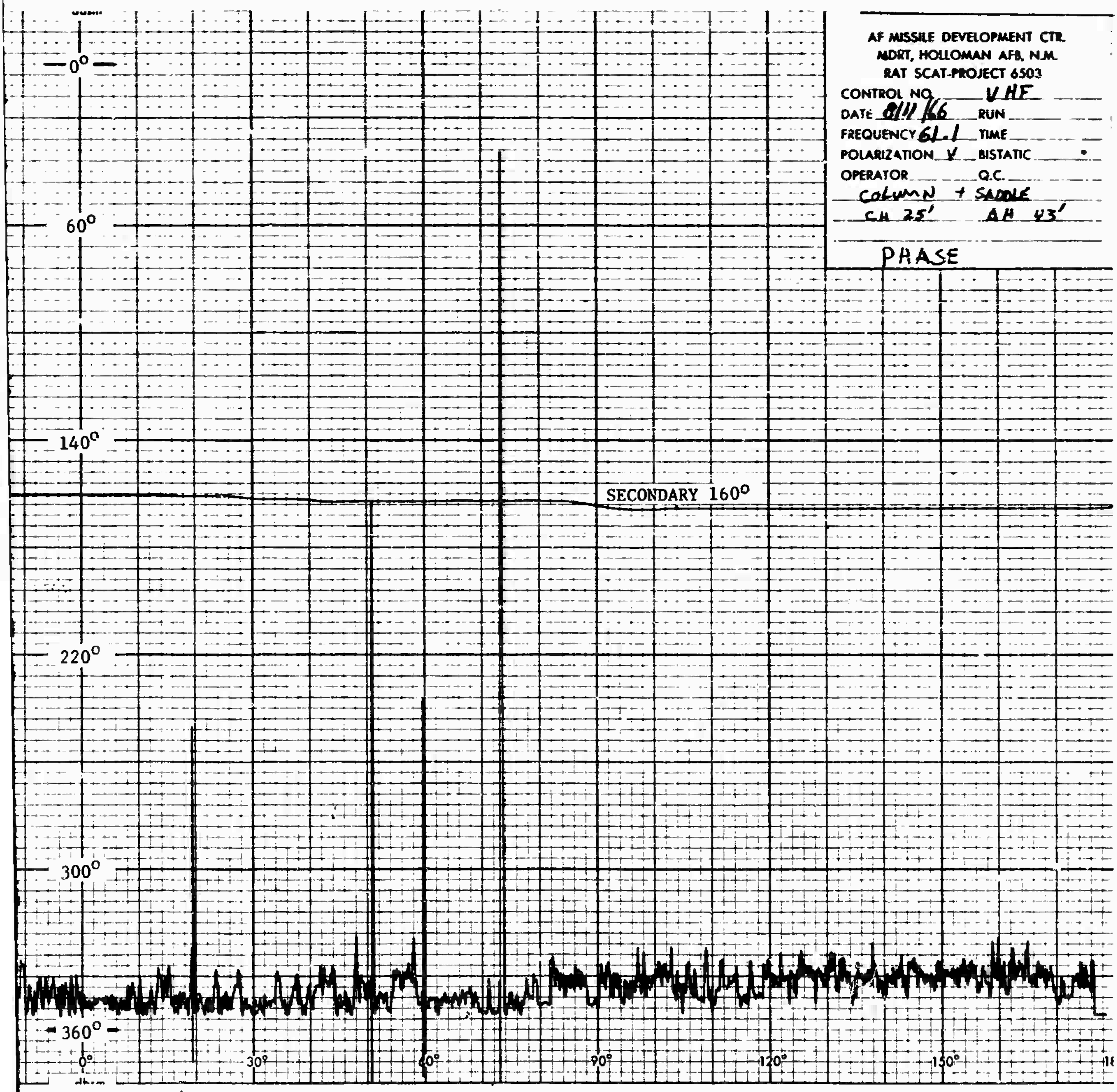
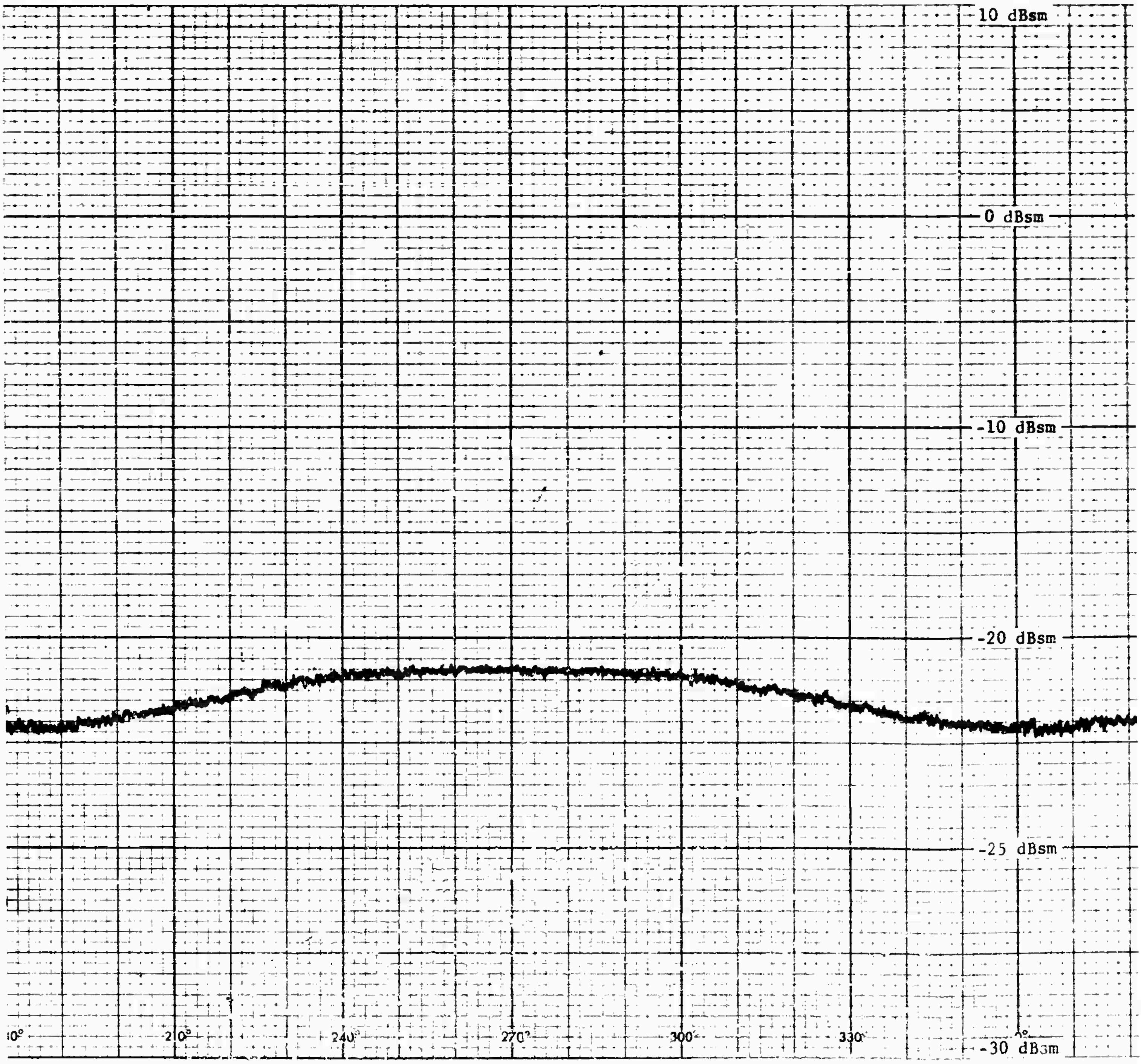


Figure 50


AF MISSILE DEVELOPMENT CTR.
MDRT, HOLLOMAN AFB, N.M.
RAT SCAT-PROJECT 6503
CONTROL NO. VHF
DATE 8/11/66 RUN
FREQUENCY 61.1 TIME
POLARIZATION V BISTATIC
OPERATOR Q.C.
COLUMN + SADDLE
CH 25' AH 43'
PHASE
0°
60°
140°
SECONDARY 160°
220°
300°
360°
0°
30°
60°
90°
120°
150°

2


10 dBsm
0 dBsm
-10 dBsm
-20 dBsm
-25 dBsm
-30 dBsm
210°
240°
270°
300°
330°

1

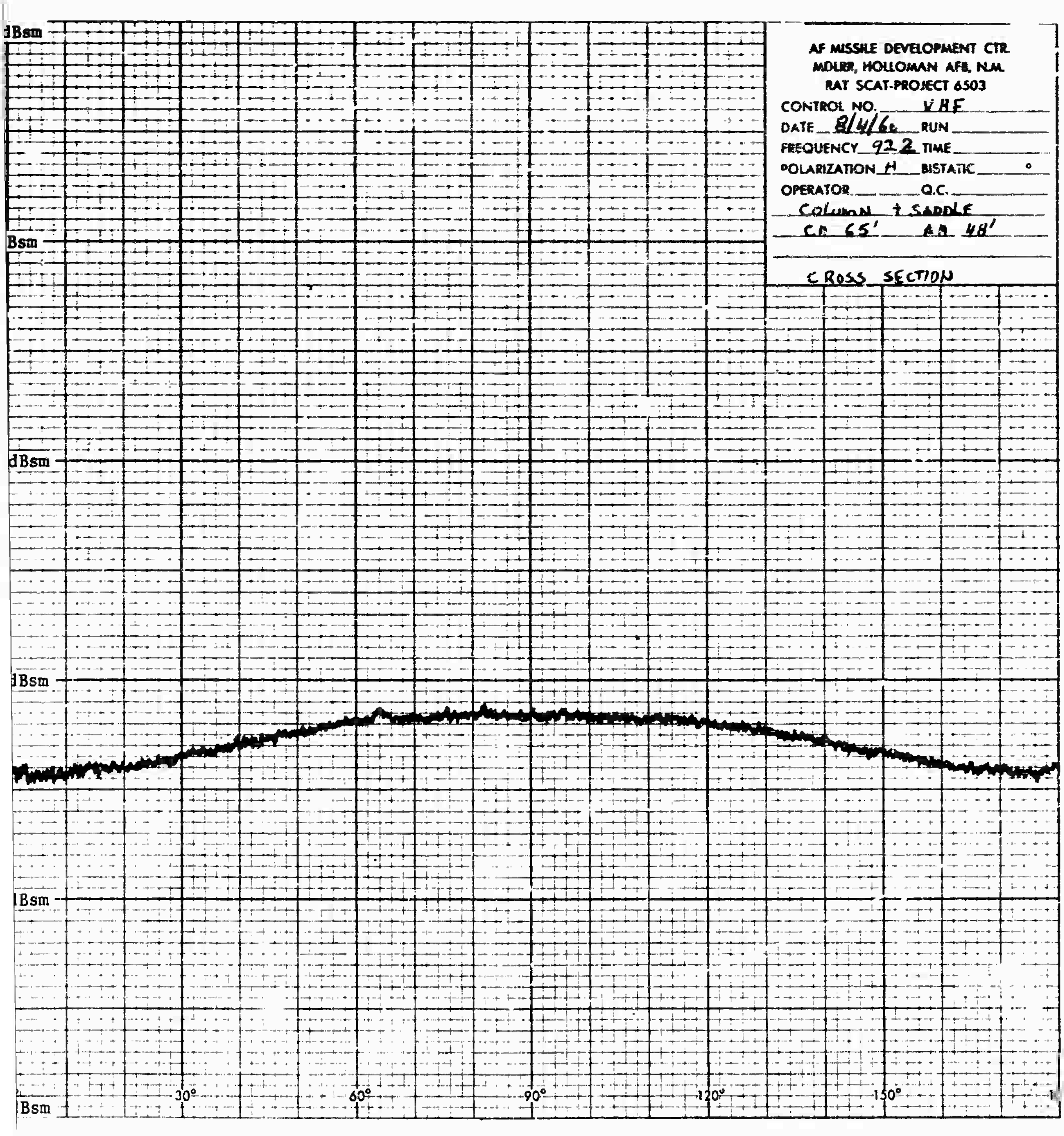

AF MISSILE DEVELOPMENT CTR.
MDLRR, HOLLOMAN AFB, N.M.
RAT SCAT-PROJECT 6503
CONTROL NO. VHF
DATE 8/4/66 RUN
FREQUENCY 922 TIME
POLARIZATION H BISTATIC °
OPERATOR Q.C.
Column + Saddle
CD 65' AB 48'
CROSS SECTION
dBsm
Bsm
dBsm
dBsm
lBsm
Bsm
30°
60°
90°
120°
150°

Figure 51

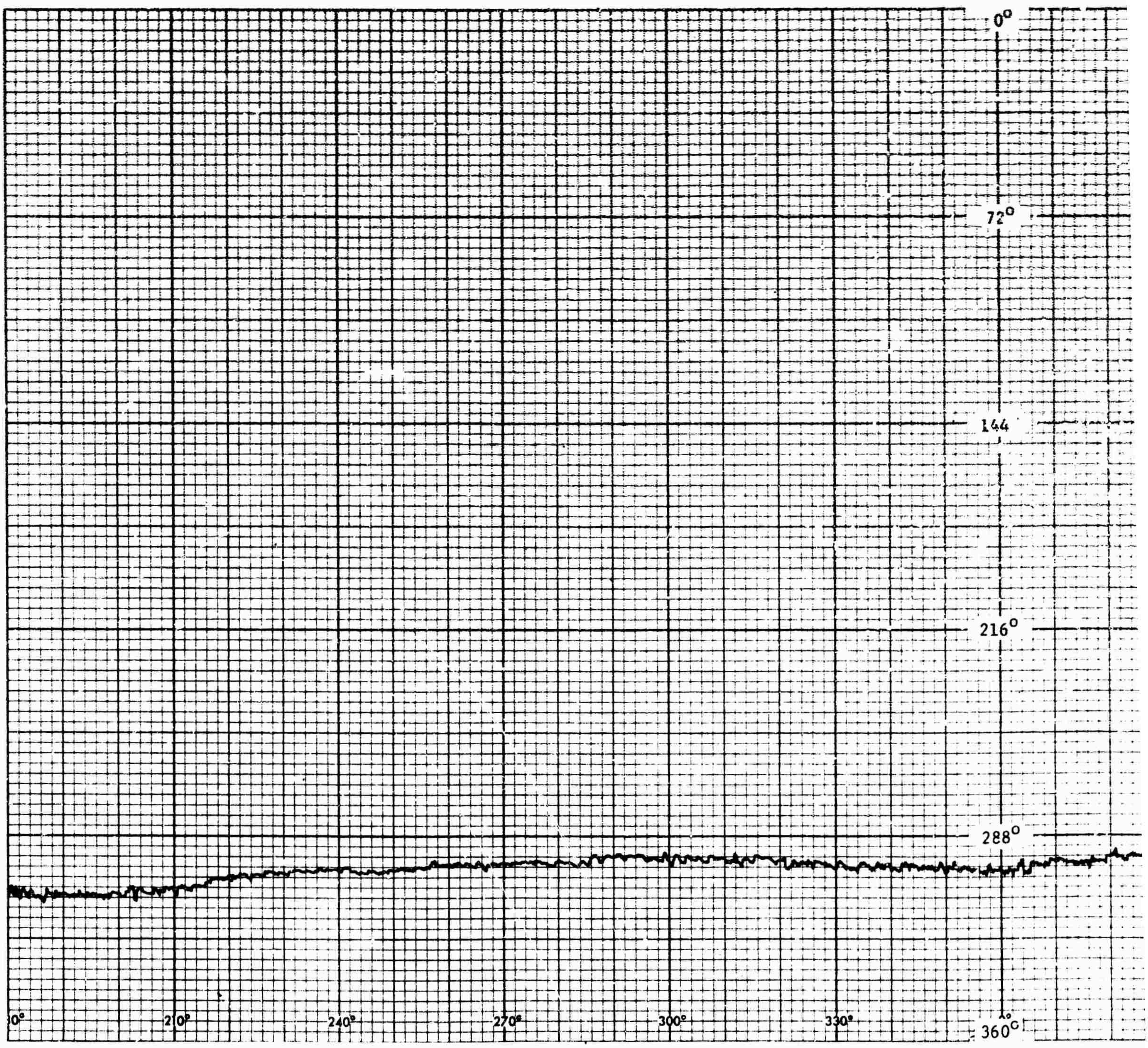
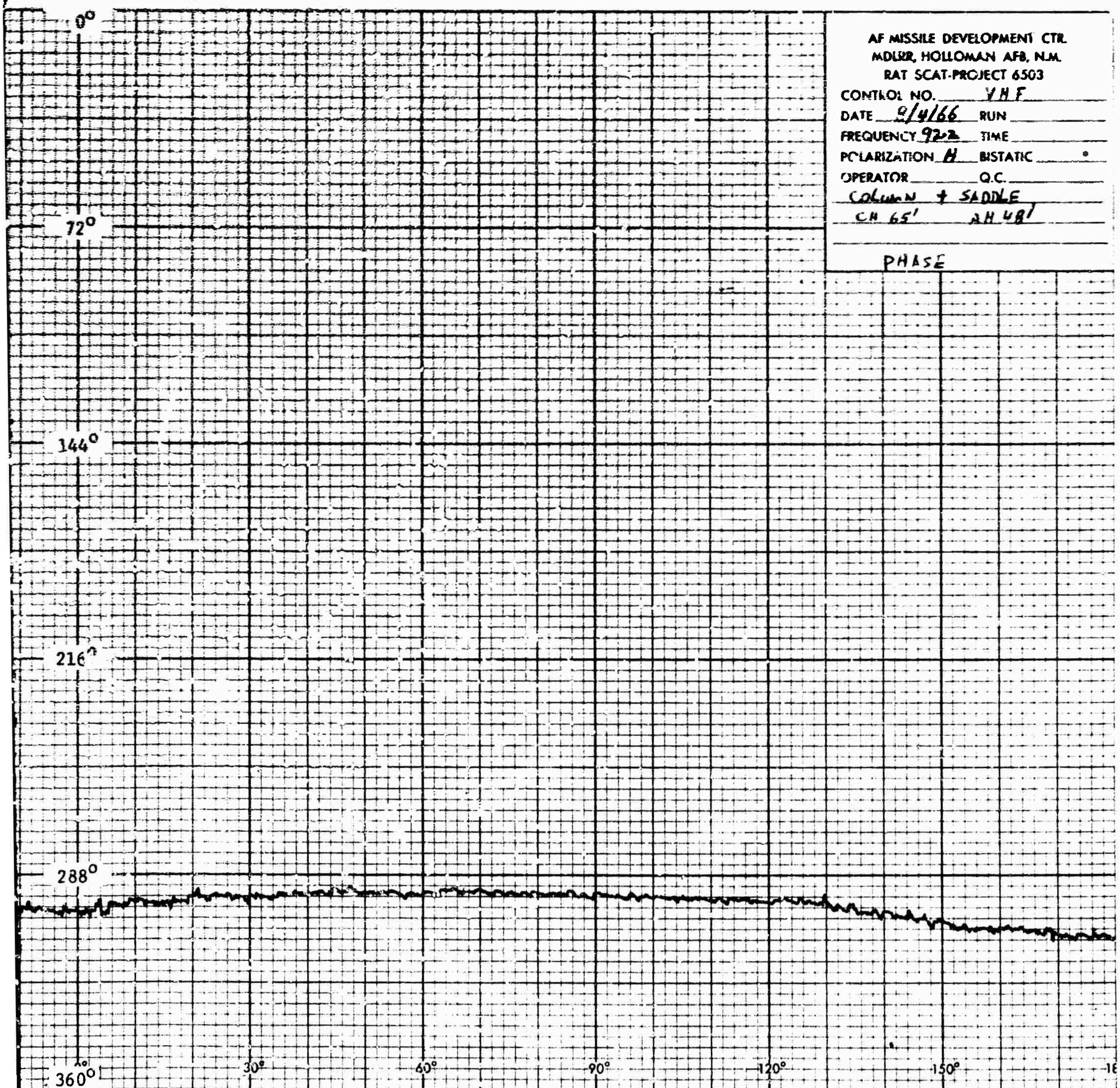
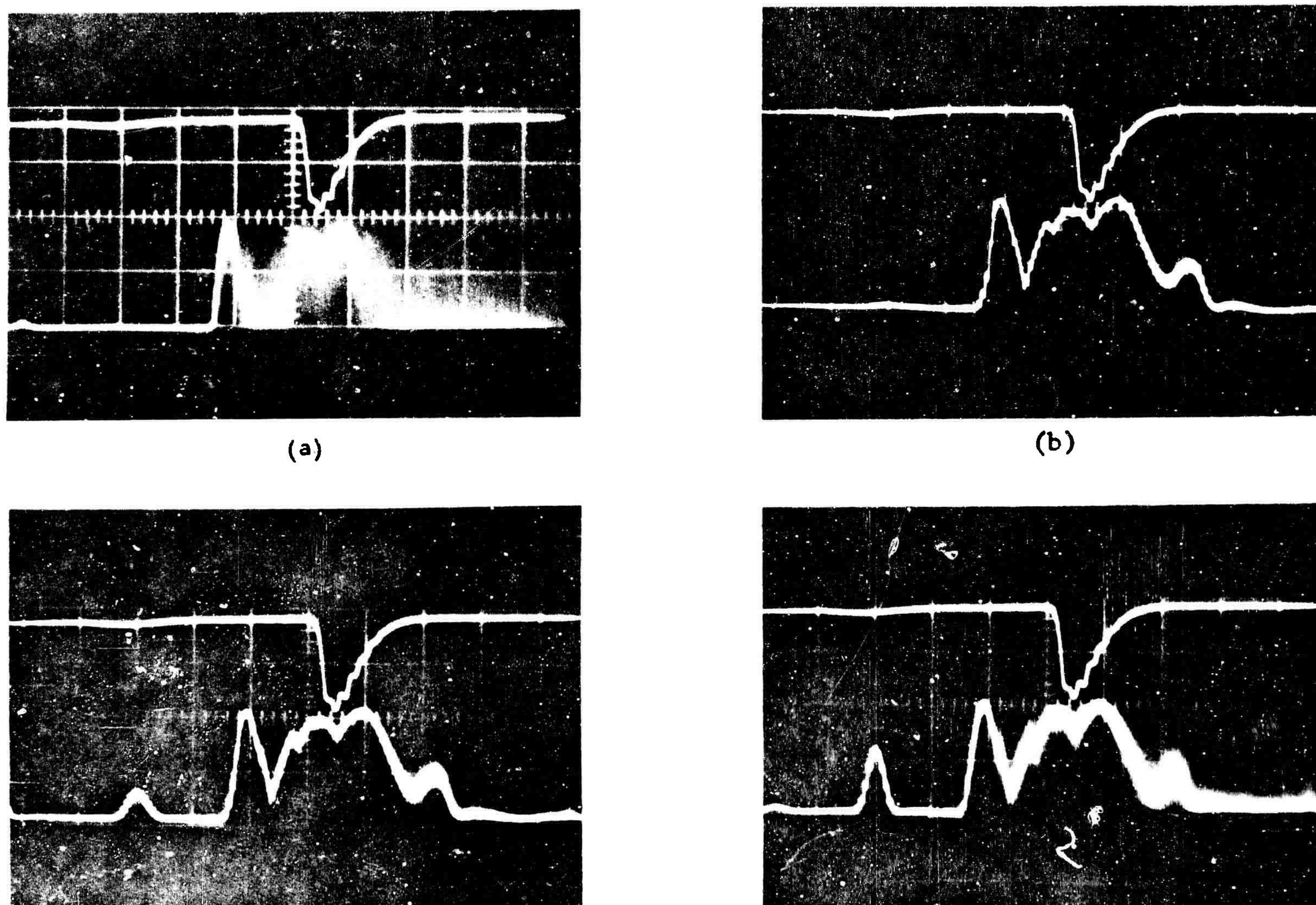


Figure 52


AF MISSILE DEVELOPMENT CTR.
MDLRR, HOLLOMAN AFB, N.M.
RAT SCAT-PROJECT 6503
CONTROL NO. VHF
DATE 8/4/66 RUN
FREQUENCY 92.2 TIME
POLARIZATION H BISTATIC
OPERATOR Q.C.
COLUMN + SADDLE
CH 65' AH 48'
PHASE
0°
72°
144°
216°
288°
360°
30°
60°
90°
120°
150°

2



(a) (b) (c) (d)

Fig. 53 RETURN NEAR PIT TIME (100' TRANSMITTER FEED LINE)

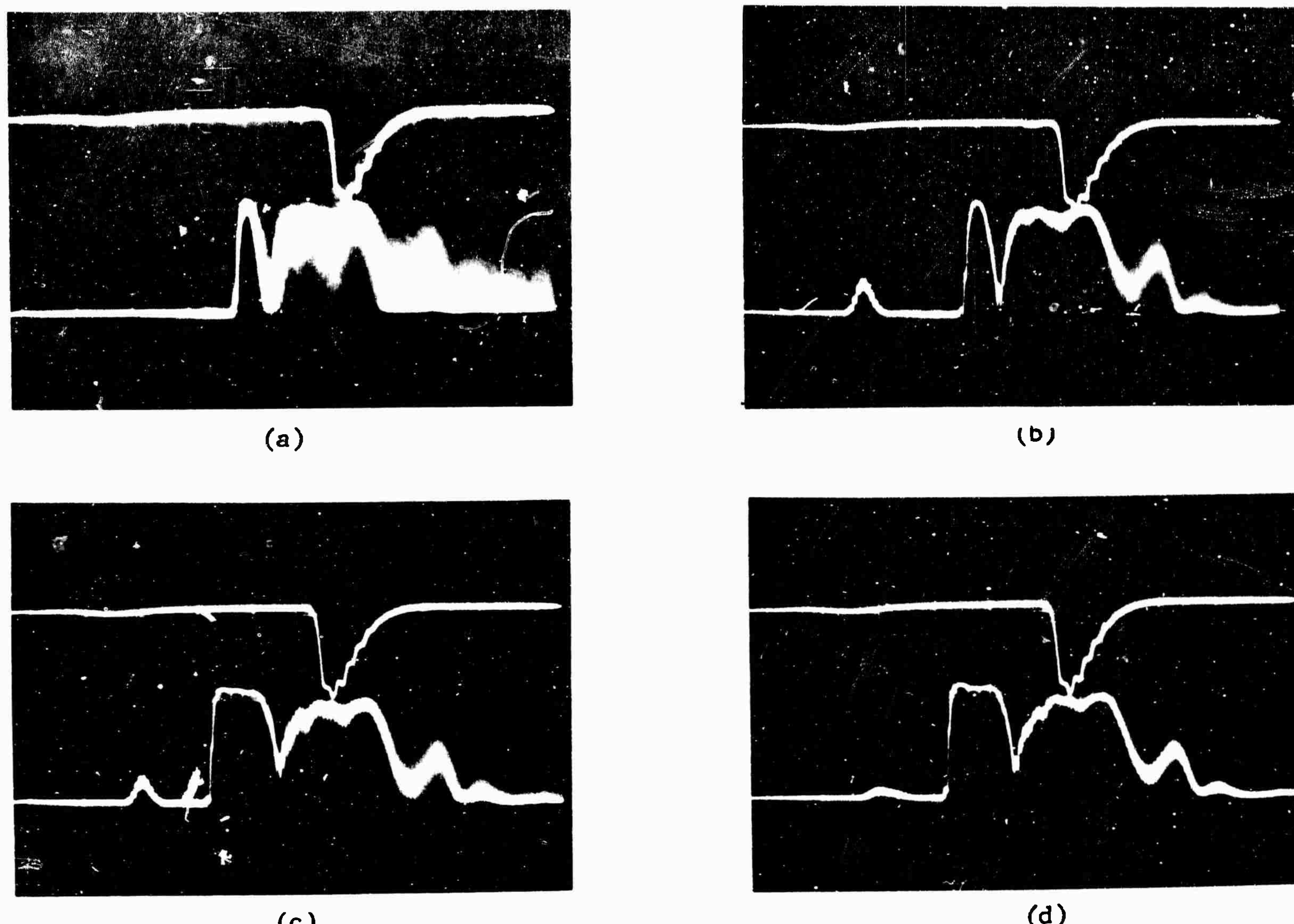
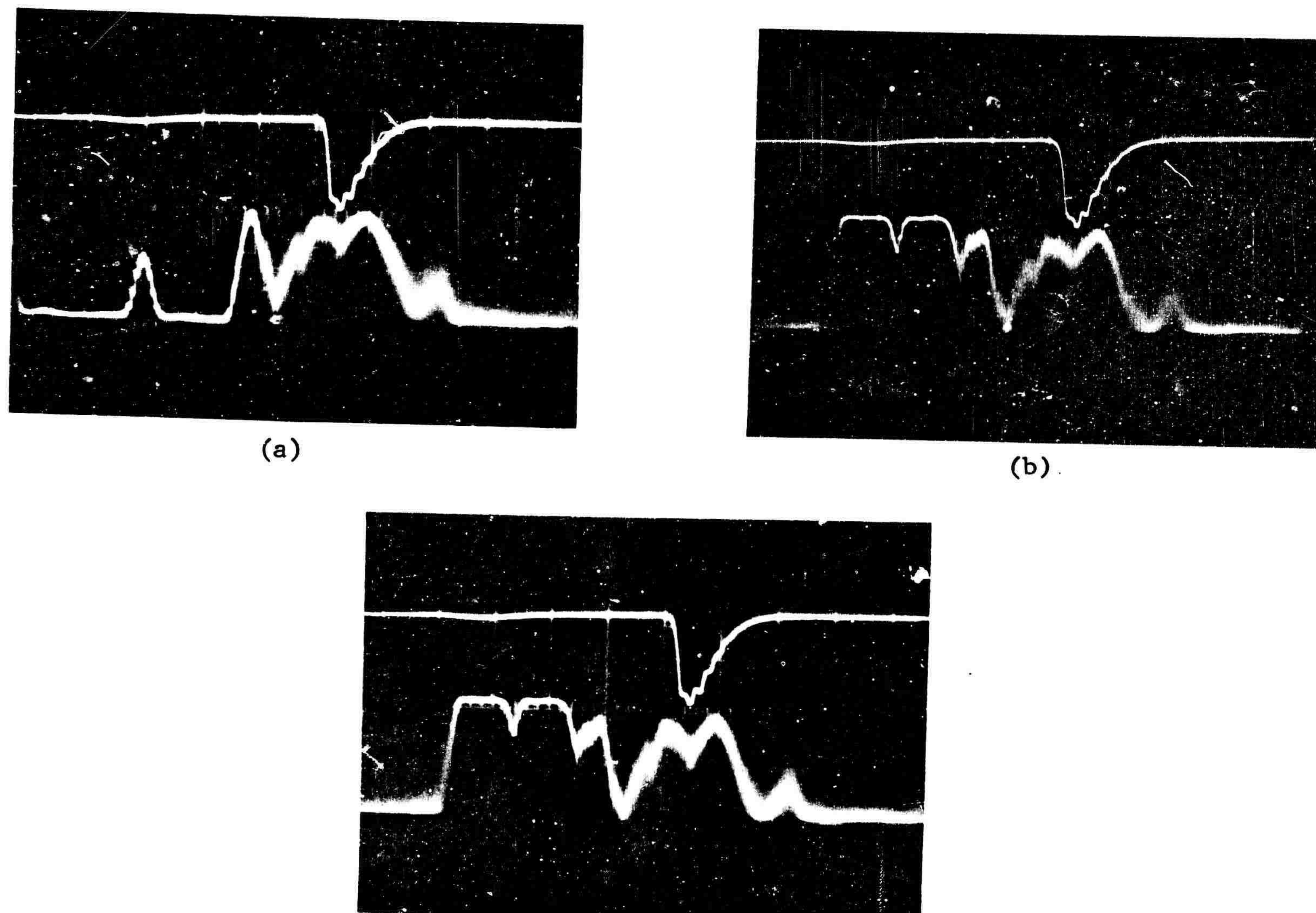


Fig. 54 RETURN NEAR PIT TIME (400' TRANSMITTER FEED LINE)



(a) (b) (c)

Fig. 55 RETURN NEAR PIT TIME WITH AND WITHOUT COLUMN

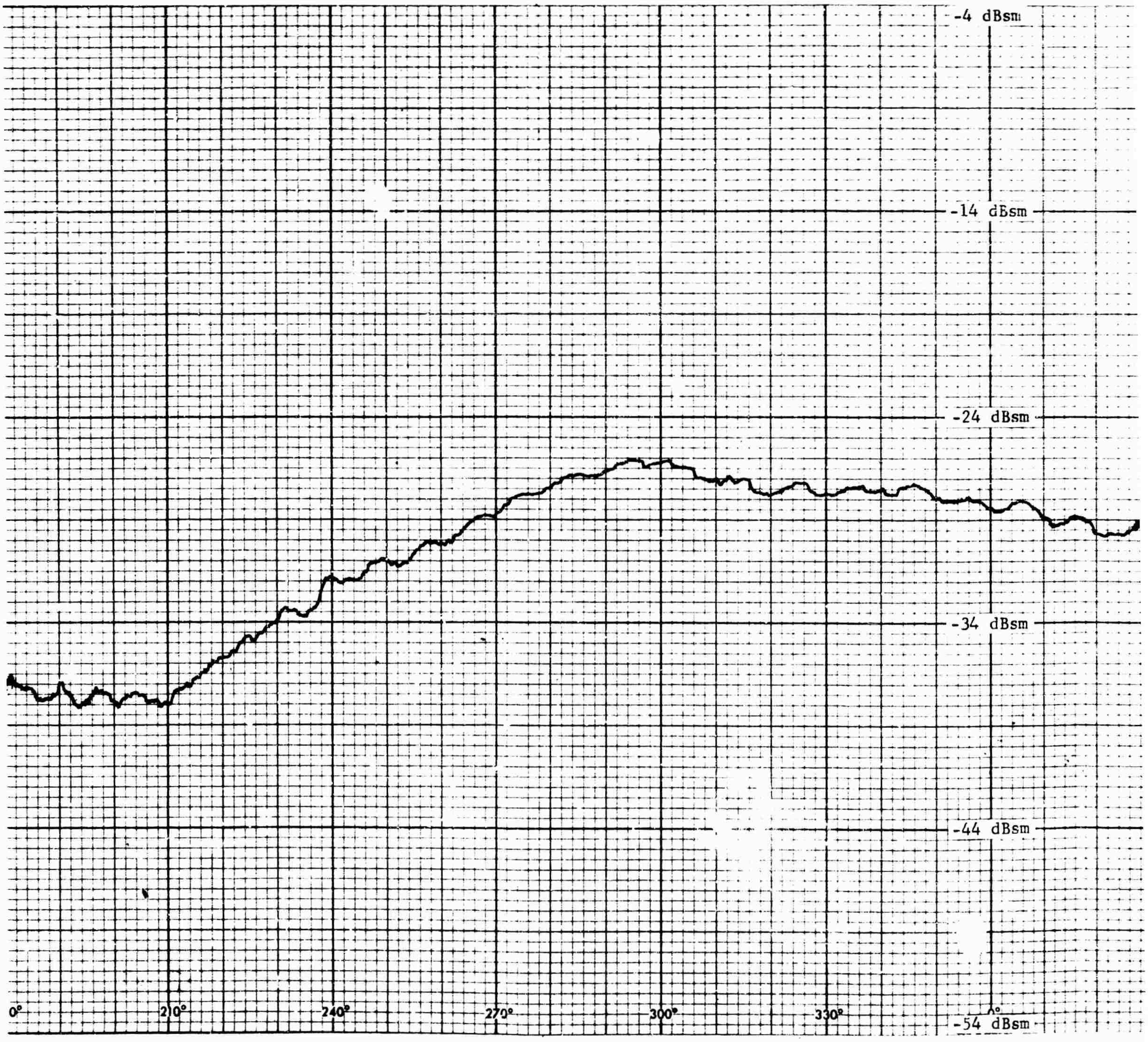
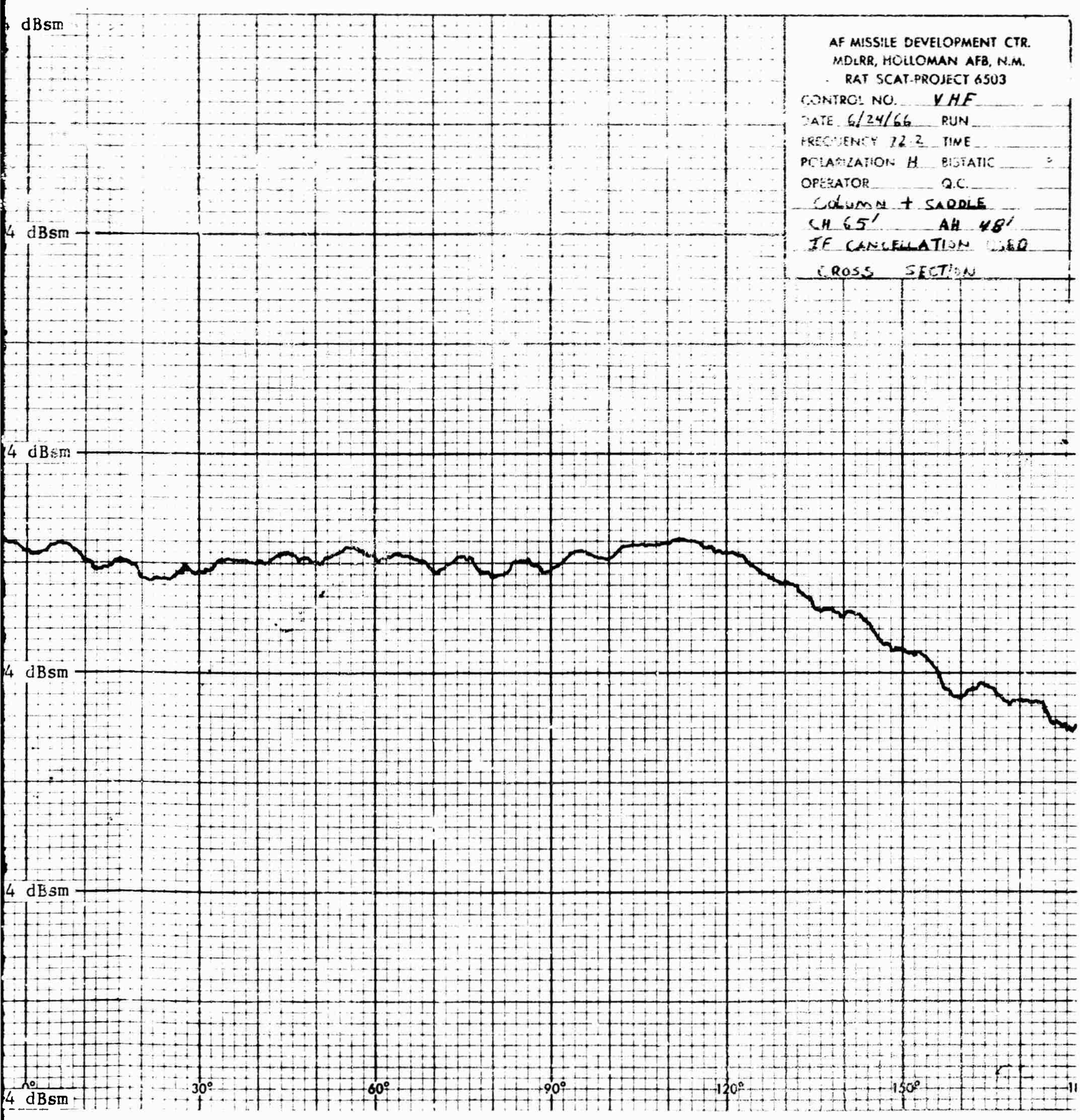
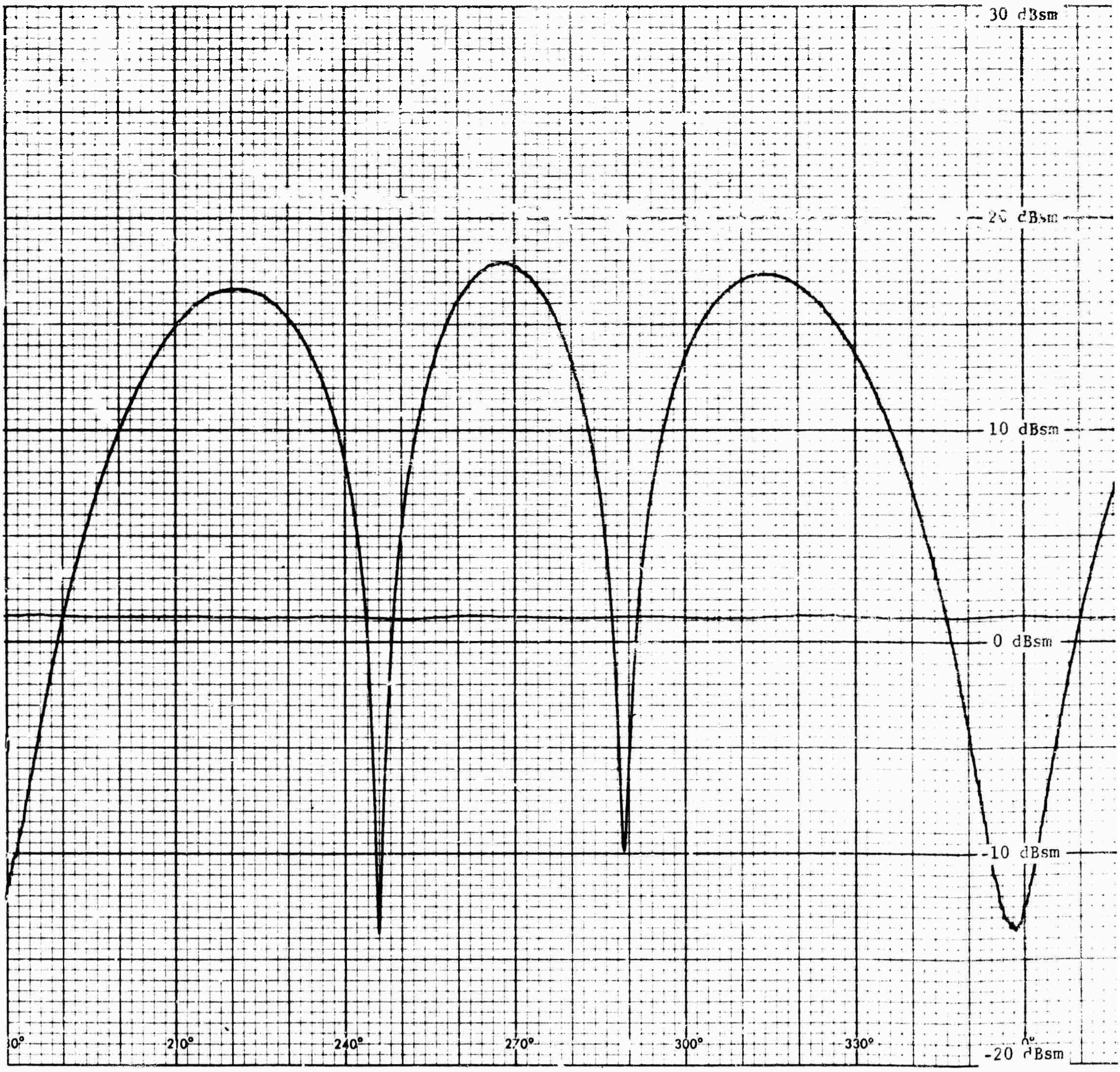

-4 dBsm
-14 dBsm
-24 dBsm
-34 dBsm
-44 dBsm
-54 dBsm
0°
210°
240°
270°
300°
330°
0°

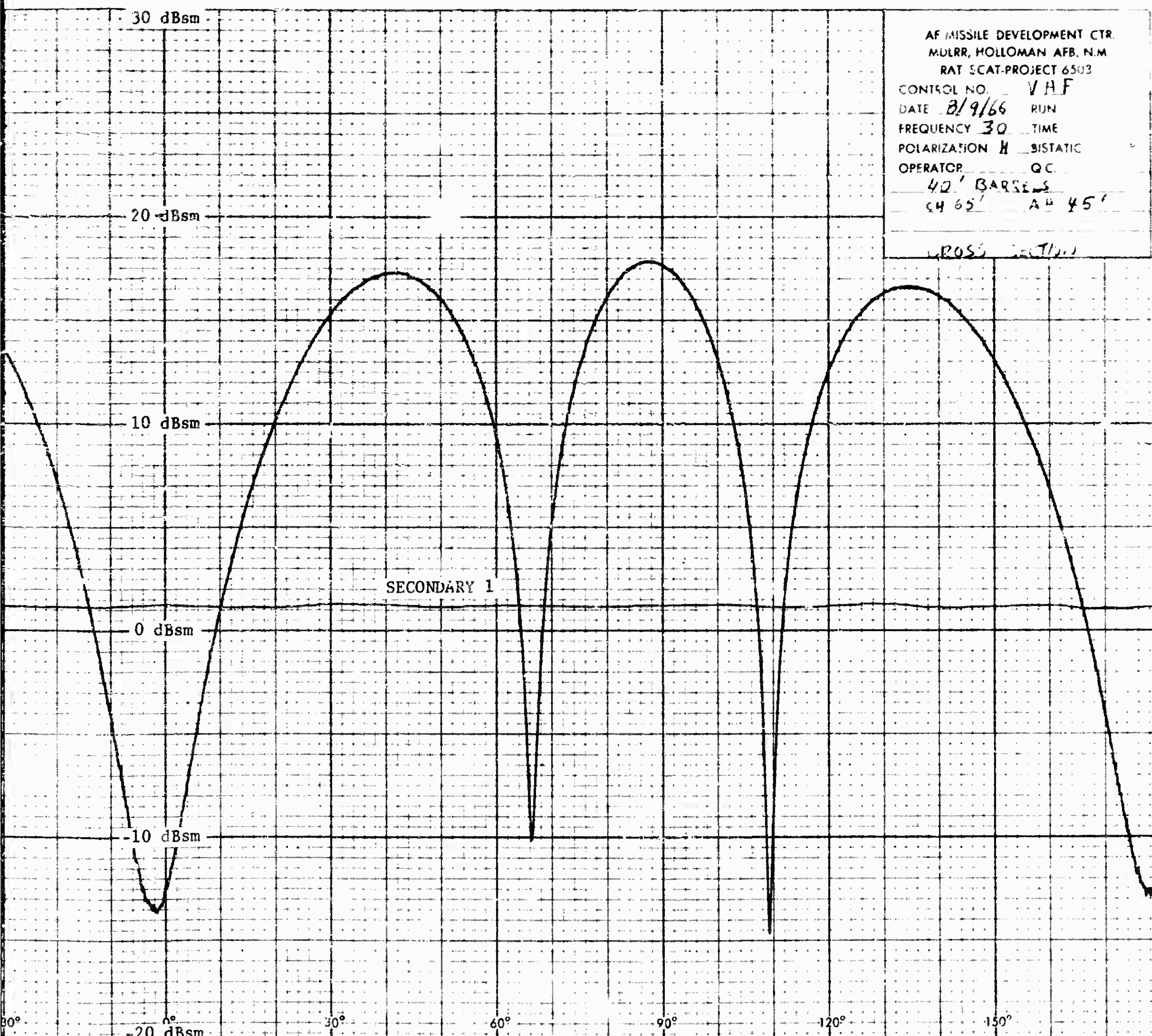
Figure 56


dBsm
4 dBsm
4 dBsm
4 dBsm
4 dBsm
4 dBsm
AF MISSILE DEVELOPMENT CTR.
MDLRR, HOLLOMAN AFB, N.M.
RAT SCAT-PROJECT 6503
CONTROL NO. VHF
DATE 6/24/66 RUN
FREQUENCY 72.2 TIME
POLARIZATION H BISTATIC
OPERATOR Q.C.
Column + SADDLE
CH 65' AH 48'
IF CANCELLATION USED
CROSS SECTION
0°
30°
60°
90°
120°
150°

2


30 dBsm
20 dBsm
10 dBsm
0 dBsm
-10 dBsm
-20 dBsm
210°
240°
270°
300°
330°

1



30 dBsm
20 dBsm
10 dBsm
0 dBsm
-10 dBsm
-20 dBsm
SECONDARY 1
0°
30°
60°
90°
120°
150°
AF MISSILE DEVELOPMENT CTR
MDLRR, HOLLOMAN AFB, N.M
RAT SCAT-PROJECT 6503
CONTROL NO. VHF
DATE 8/9/66 RUN
FREQUENCY 30 TIME
POLARIZATION H BISTATIC
OPERATOR QC
40' BARSELS

Figure 57

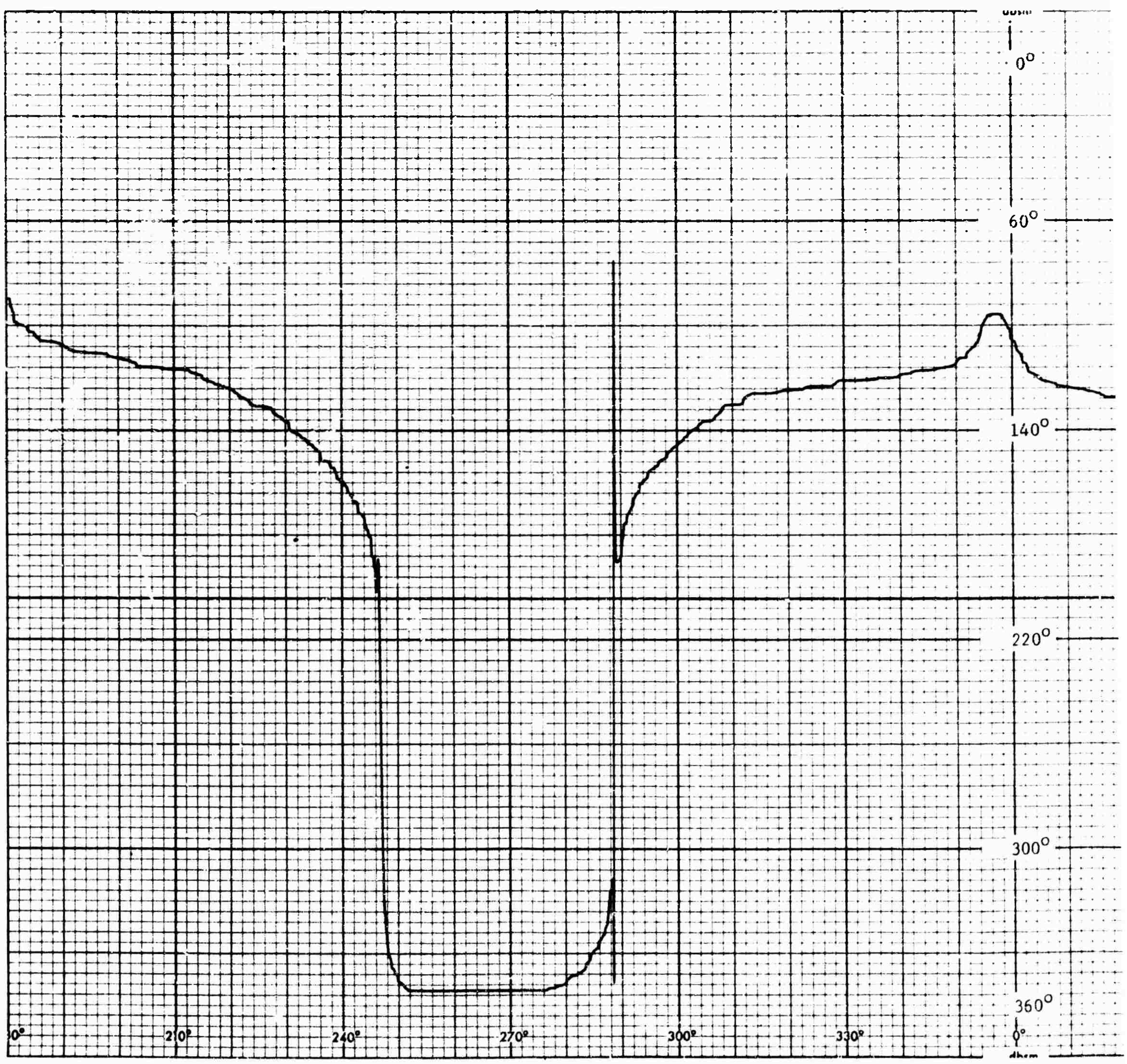
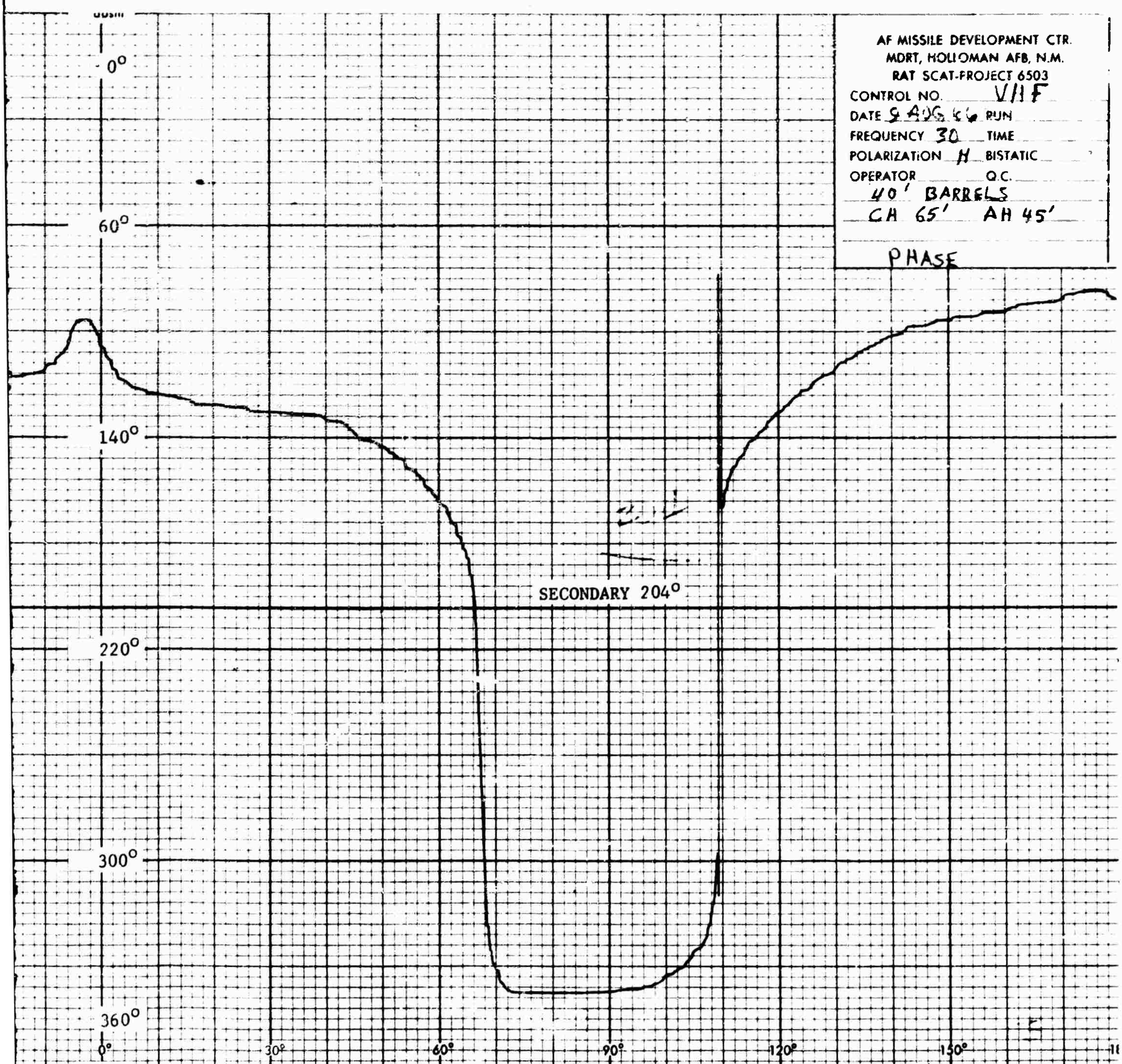
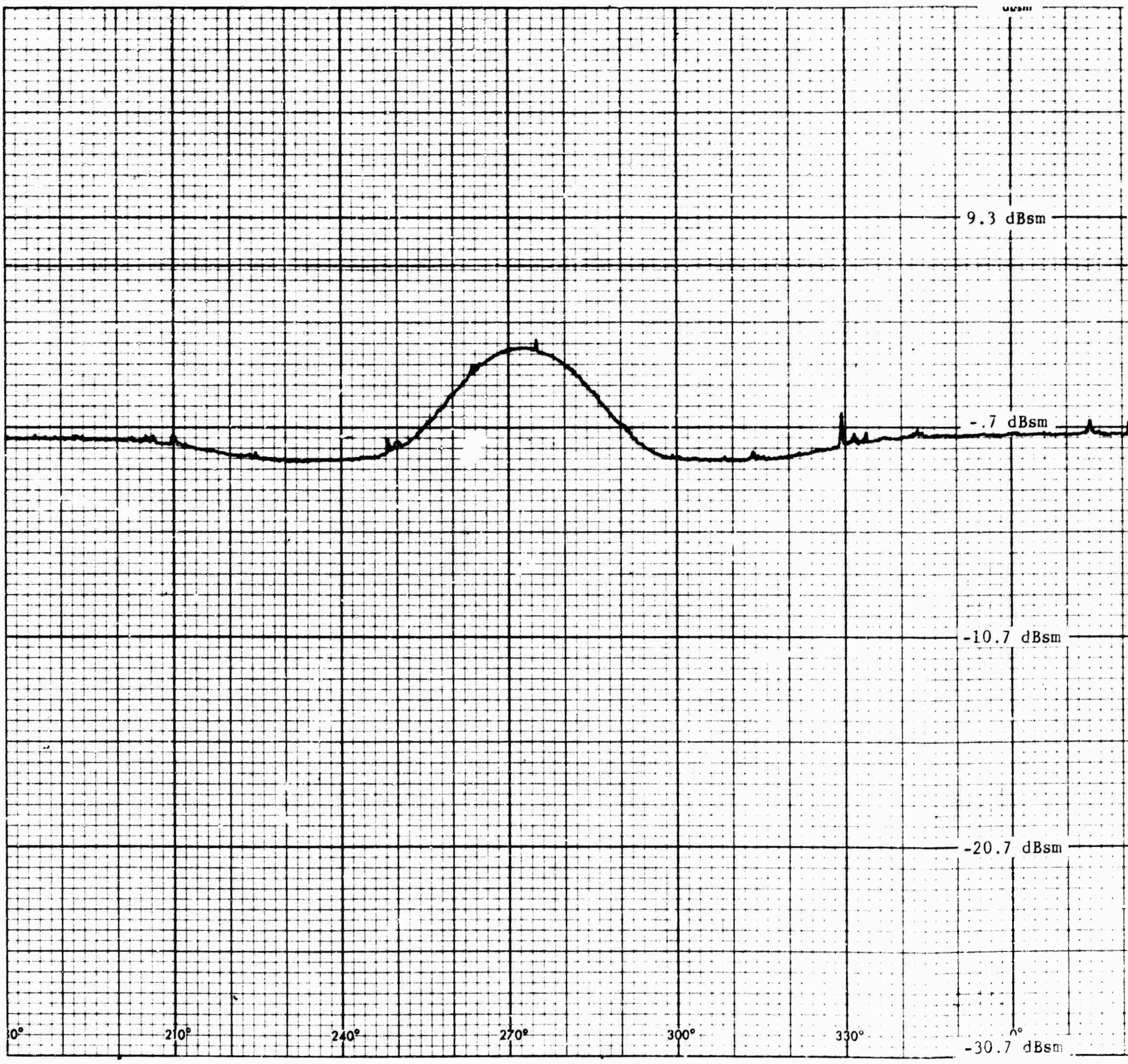


Figure 58



AF MISSILE DEVELOPMENT CTR.
MDRT, HOLLOMAN AFB, N.M.
RAT SCAT-PROJECT 6503
CONTROL NO. V/1F
DATE 9 AUG 66 RUN
FREQUENCY 30 TIME
POLARIZATION H BISTATIC
OPERATOR Q.C.
40' BARRELS
CH 65' AH 45'
PHASE
0°
60°
140°
SECONDARY 204°
220°
300°
360°
0°
30°
60°
90°
120°
150°

2



1

2

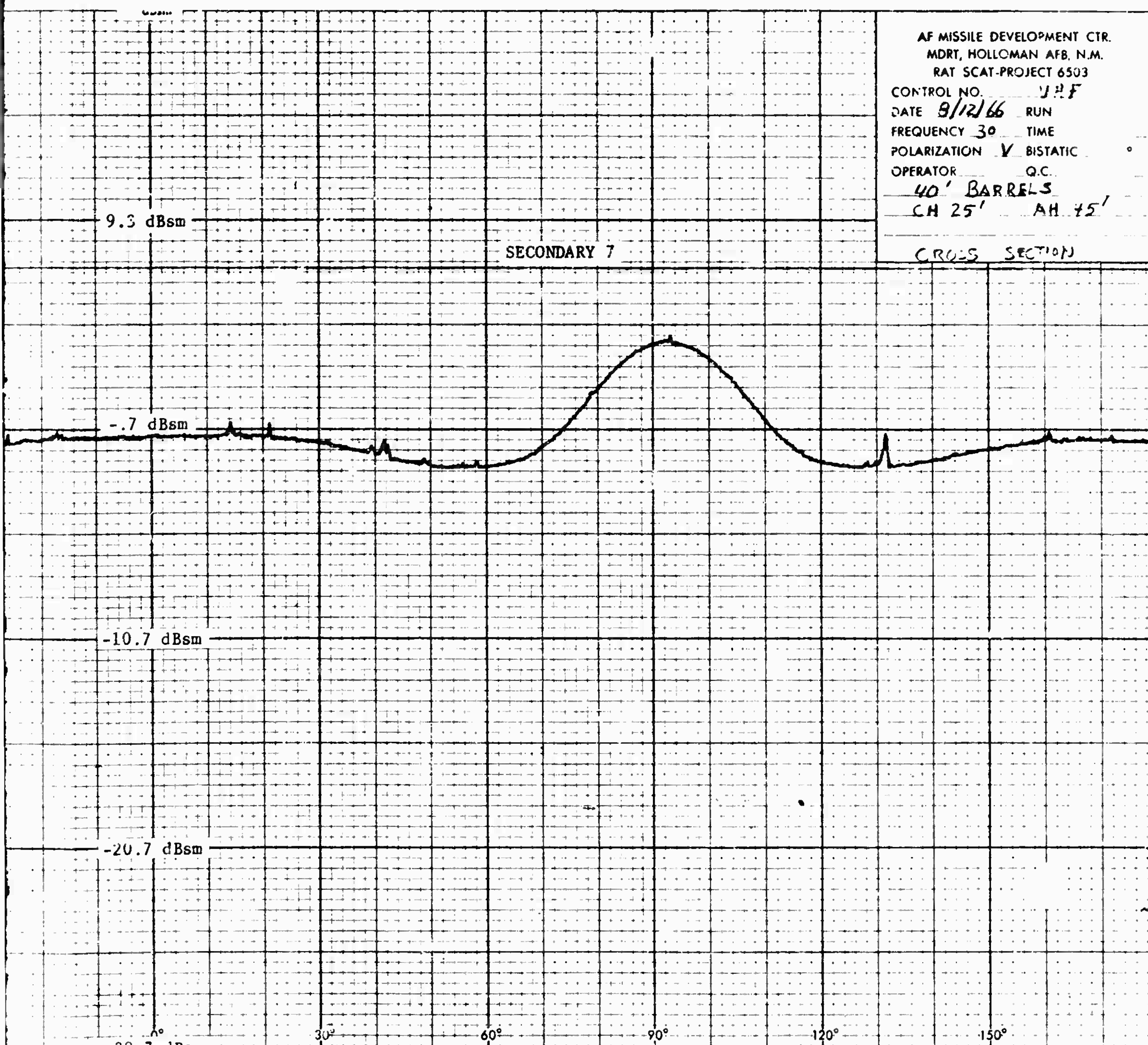

AF MISSILE DEVELOPMENT CTR.
MDRT, HOLLOMAN AFB, N.M.
RAT SCAT-PROJECT 6503
CONTROL NO. 9RF
DATE 8/12/66 RUN
FREQUENCY 30 TIME
POLARIZATION V BISTATIC
OPERATOR Q.C.
40' BARRELS
CH 25' AH 45'
CROSS SECTION
9.3 dBsm
SECONDARY 7
-.7 dBsm
-10.7 dBsm
-20.7 dBsm
-30.7 dBsm
0°
30°
60°
90°
120°
150°

Figure 59

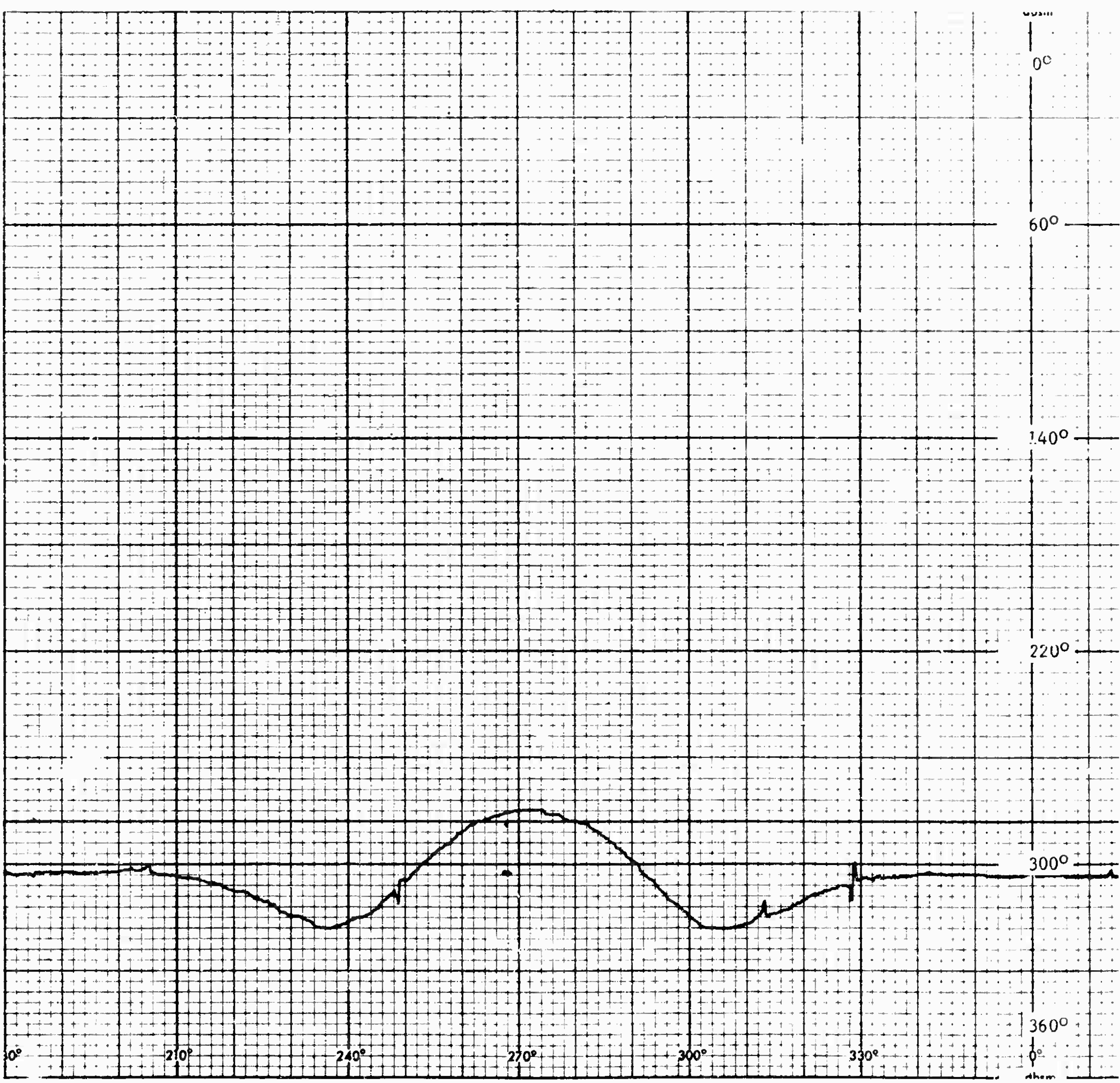
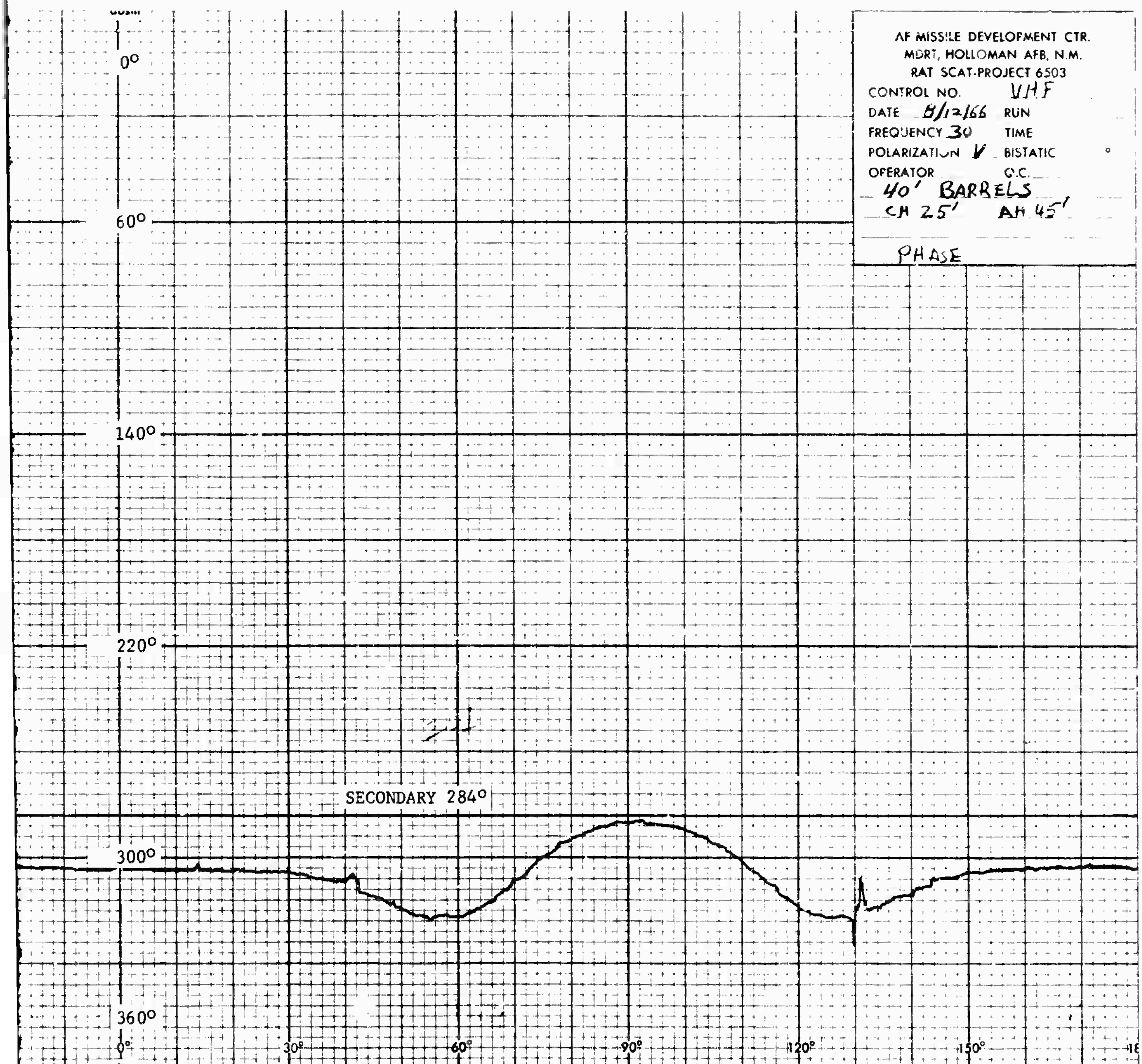
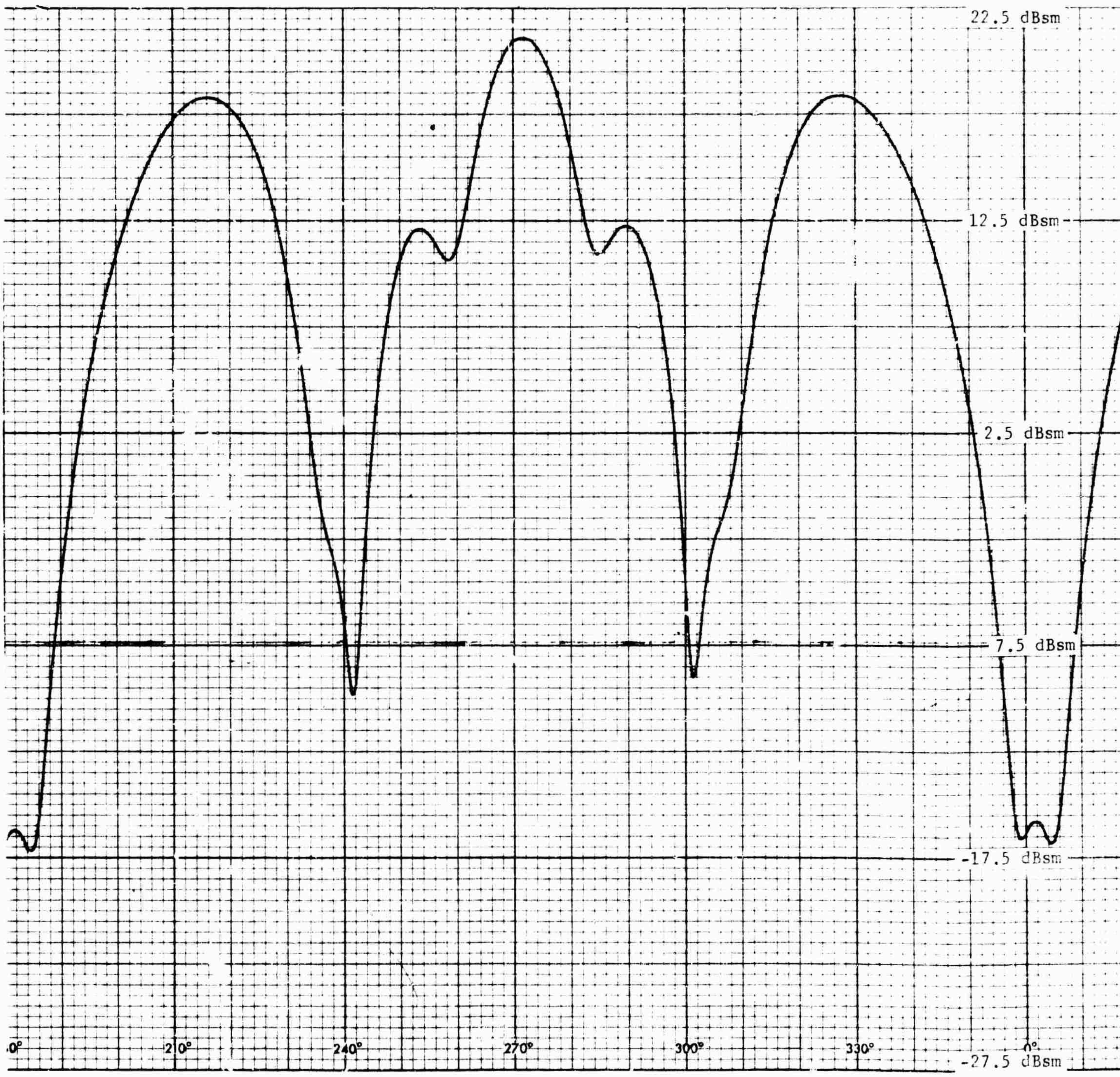


Figure 60

2


AF MISSILE DEVELOPMENT CTR.
MDRT, HOLLOMAN AFB, N.M.
RAT SCAT-PROJECT 6503
CONTROL NO. VHF
DATE 8/12/66 RUN
FREQUENCY 30 TIME
POLARIZATION V BISTATIC °
OPERATOR O.C.
40' BARRELS
CH 25' AH 45'
PHASE
0°
60°
140°
220°
SECONDARY 284°
300°
360°
0°
30°
60°
90°
120°
150°


22.5 dBsm
12.5 dBsm
2.5 dBsm
-7.5 dBsm
-17.5 dBsm
-27.5 dBsm
210°
240°
270°
300°
330°
0°

1

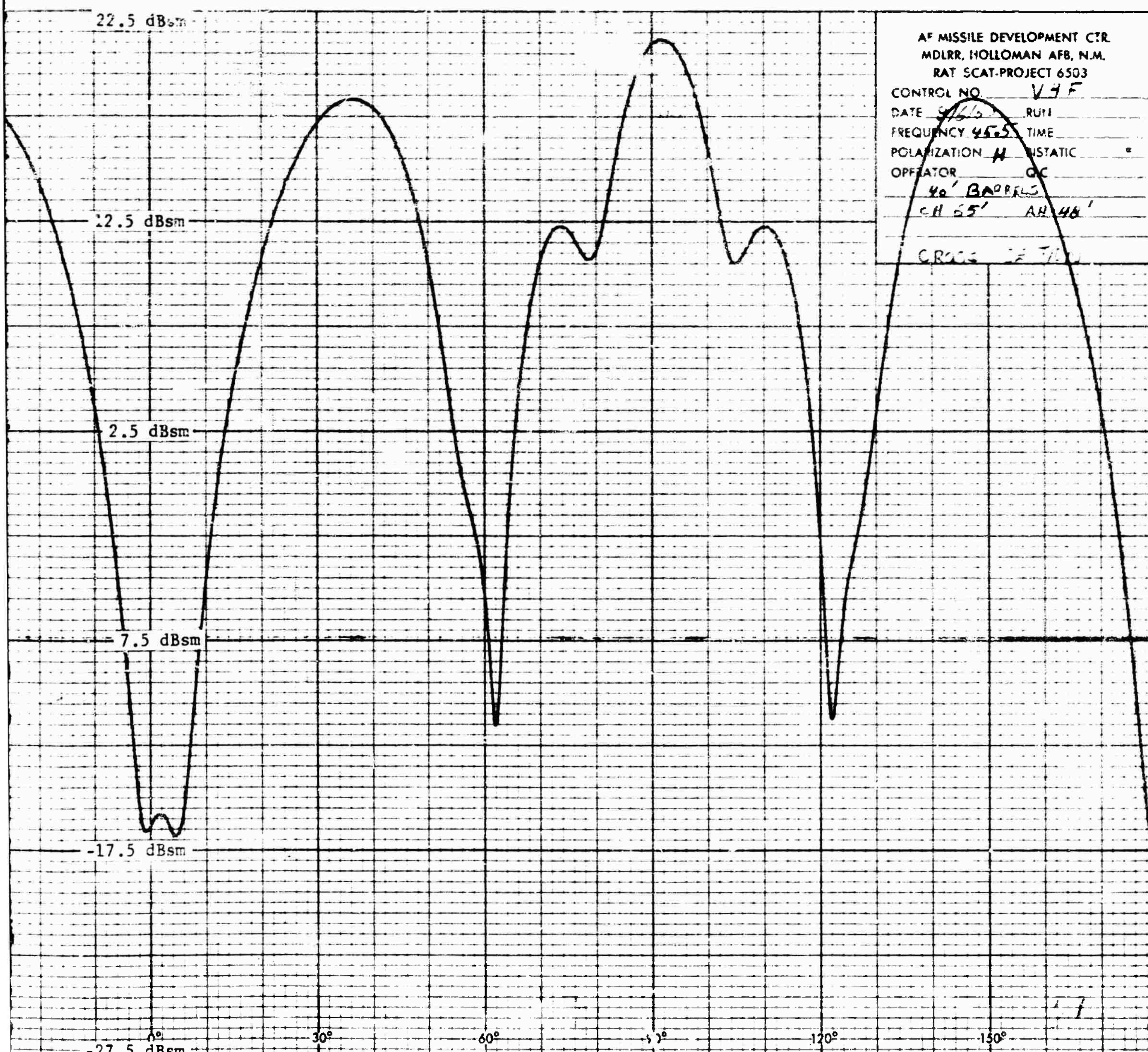
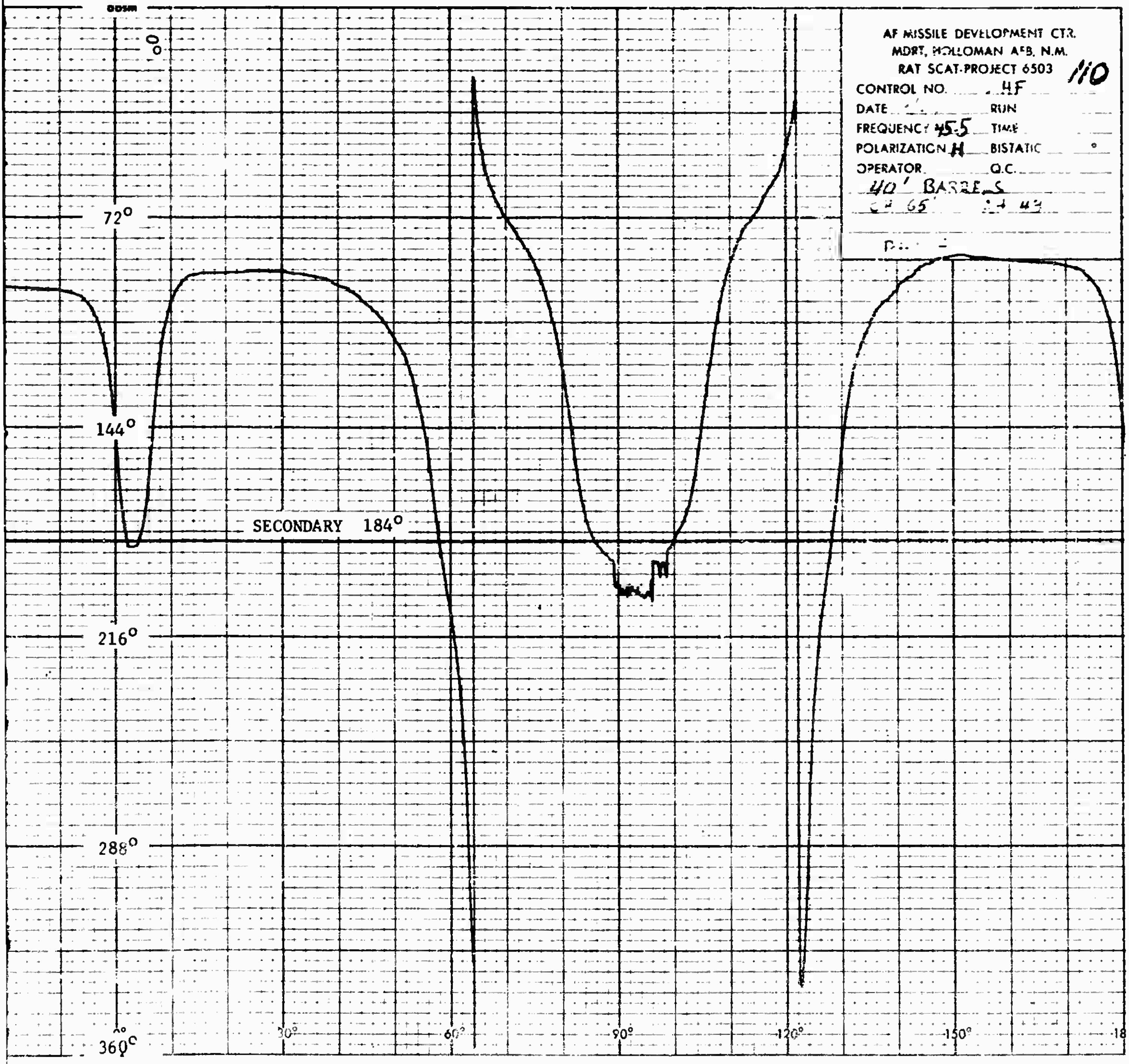
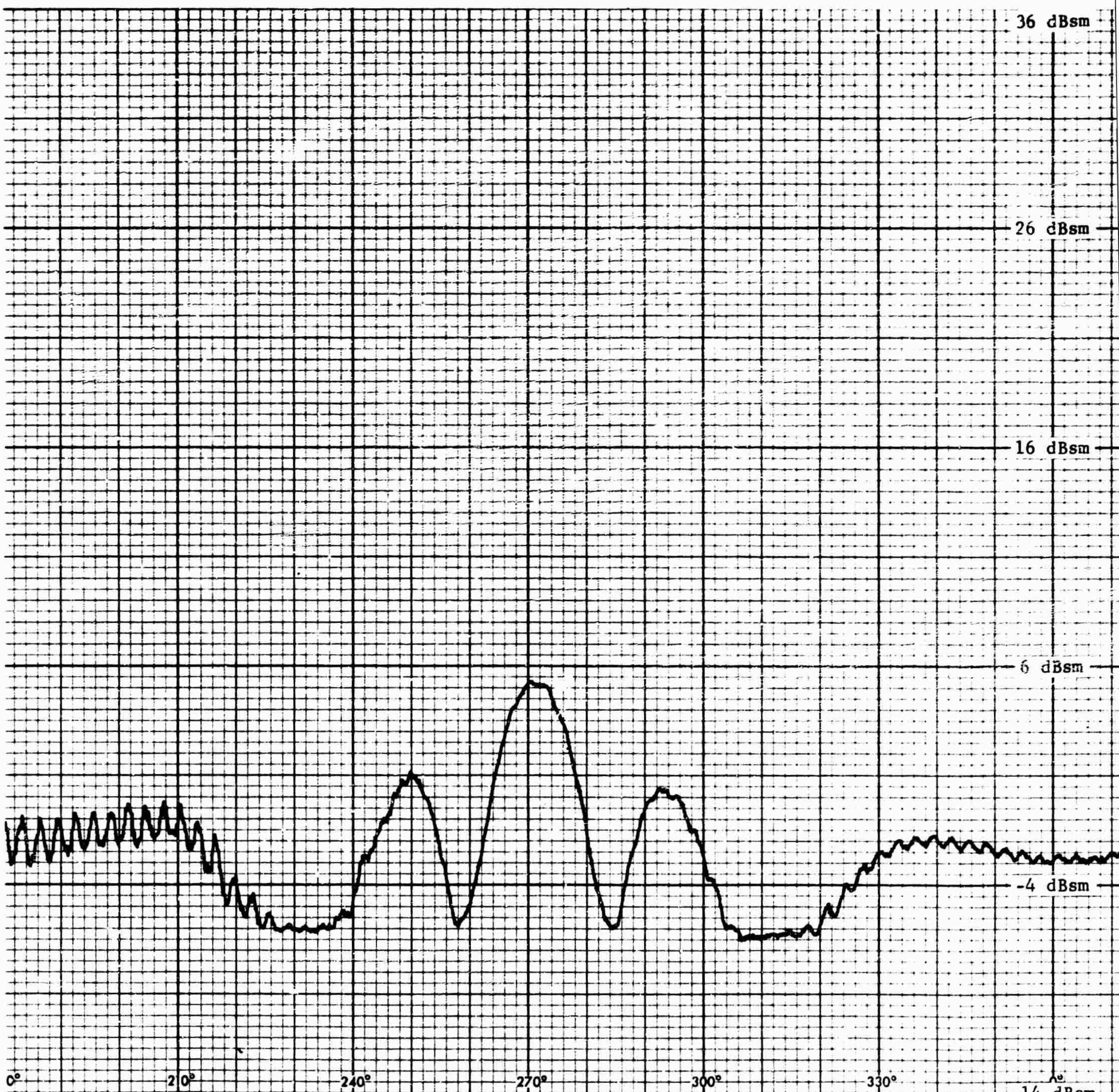

22.5 dBsm
12.5 dBsm
2.5 dBsm
-7.5 dBsm
-17.5 dBsm
-27.5 dBsm
0°
30°
60°
120°
150°
AF MISSILE DEVELOPMENT CTR.
MDLRR, HOLLOMAN AFB, N.M.
RAT SCAT-PROJECT 6503
CONTROL NO.
DATE
RUN
FREQUENCY
TIME
POLARIZATION
BISTATIC
OPERATOR
QC

Figure 61

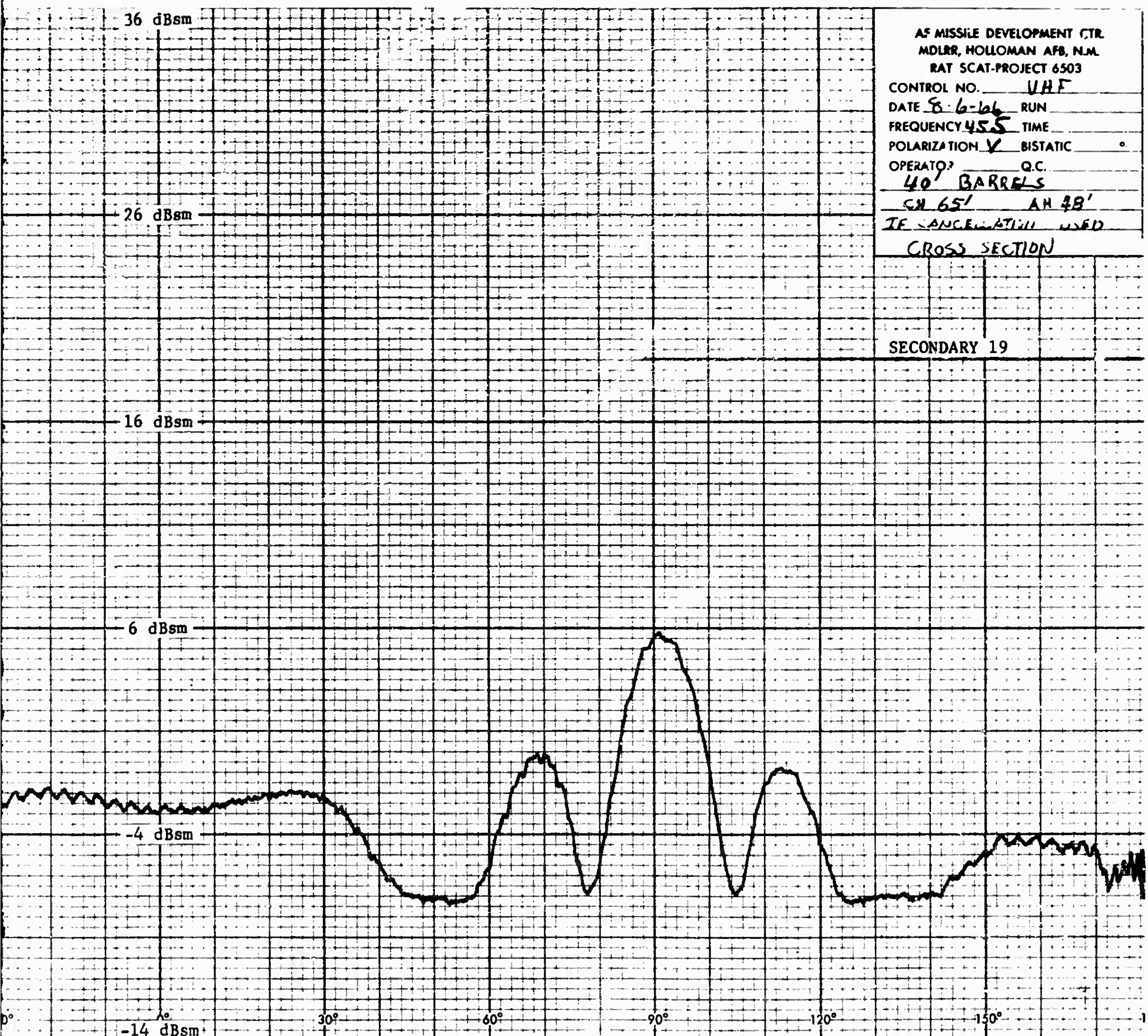
Figure 62


AF MISSILE DEVELOPMENT CTR.
MDRT, HOLLOMAN AFB, N.M.
RAT SCAT-PROJECT 6503
110
CONTROL NO.
4F
DATE
RUN
FREQUENCY 45.5
TIME
POLARIZATION H
BISTATIC
OPERATOR
Q.C.
40' BARREL
72°
144°
SECONDARY 184°
216°
288°
360°
30°
60°
90°
120°
150°

2


36 dBsm
26 dBsm
16 dBsm
6 dBsm
-4 dBsm
-14 dBsm
0°
210°
240°
270°
300°
330°

1



36 dBsm
26 dBsm
16 dBsm
6 dBsm
-4 dBsm
-14 dBsm
0°
30°
60°
90°
120°
150°
AF MISSILE DEVELOPMENT CTR.
MDLRR, HOLLOMAN AFB, N.M.
RAT SCAT-PROJECT 6503
CONTROL NO. UHF
DATE 8-6-66 RUN
FREQUENCY 455 TIME
POLARIZATION V BISTATIC °
OPERATOR Q.C.
40' BARRELS
CH 65' AH 48'
IF CANCELLATION USED
CROSS SECTION
SECONDARY 19

Figure 63

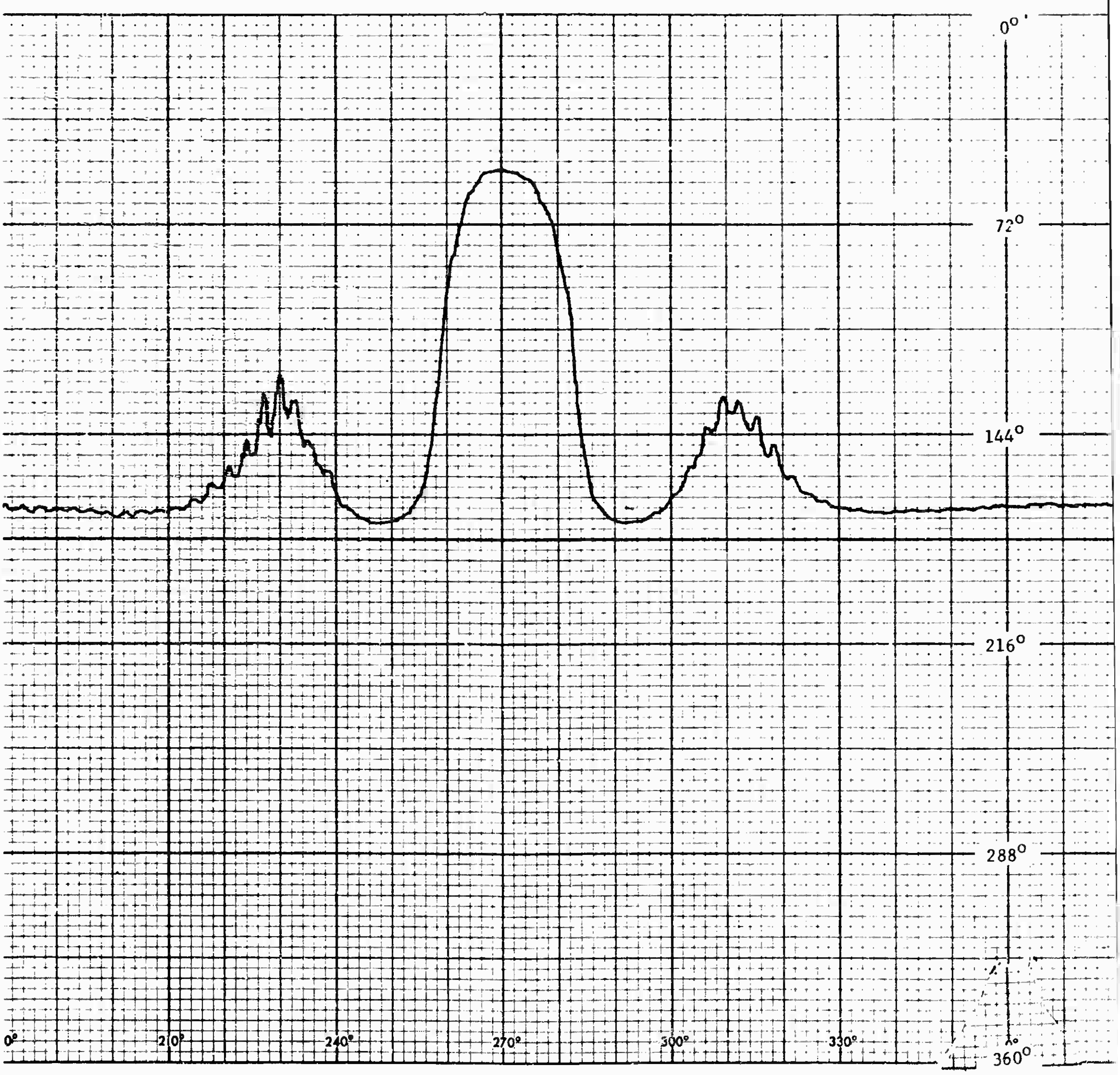
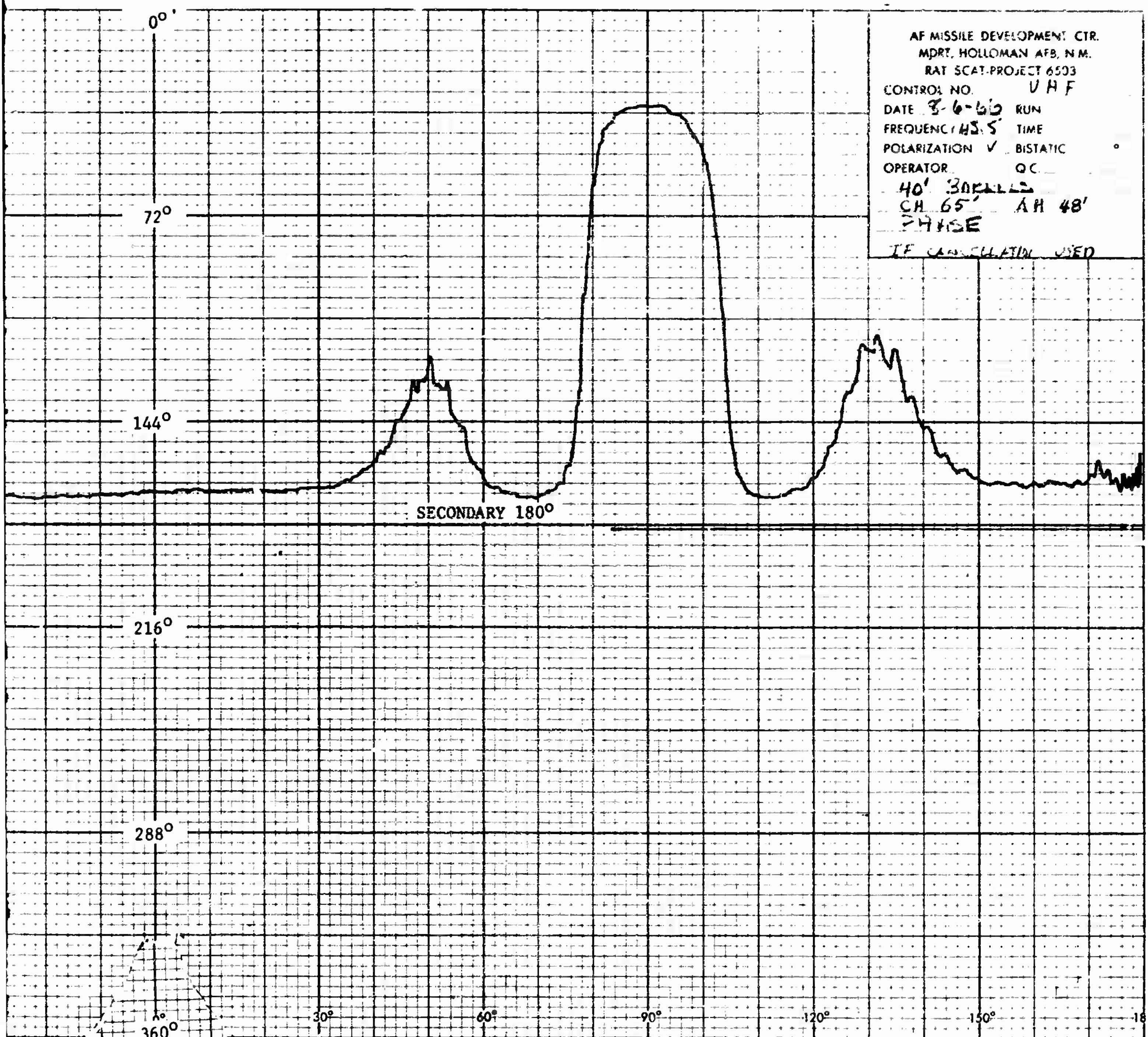
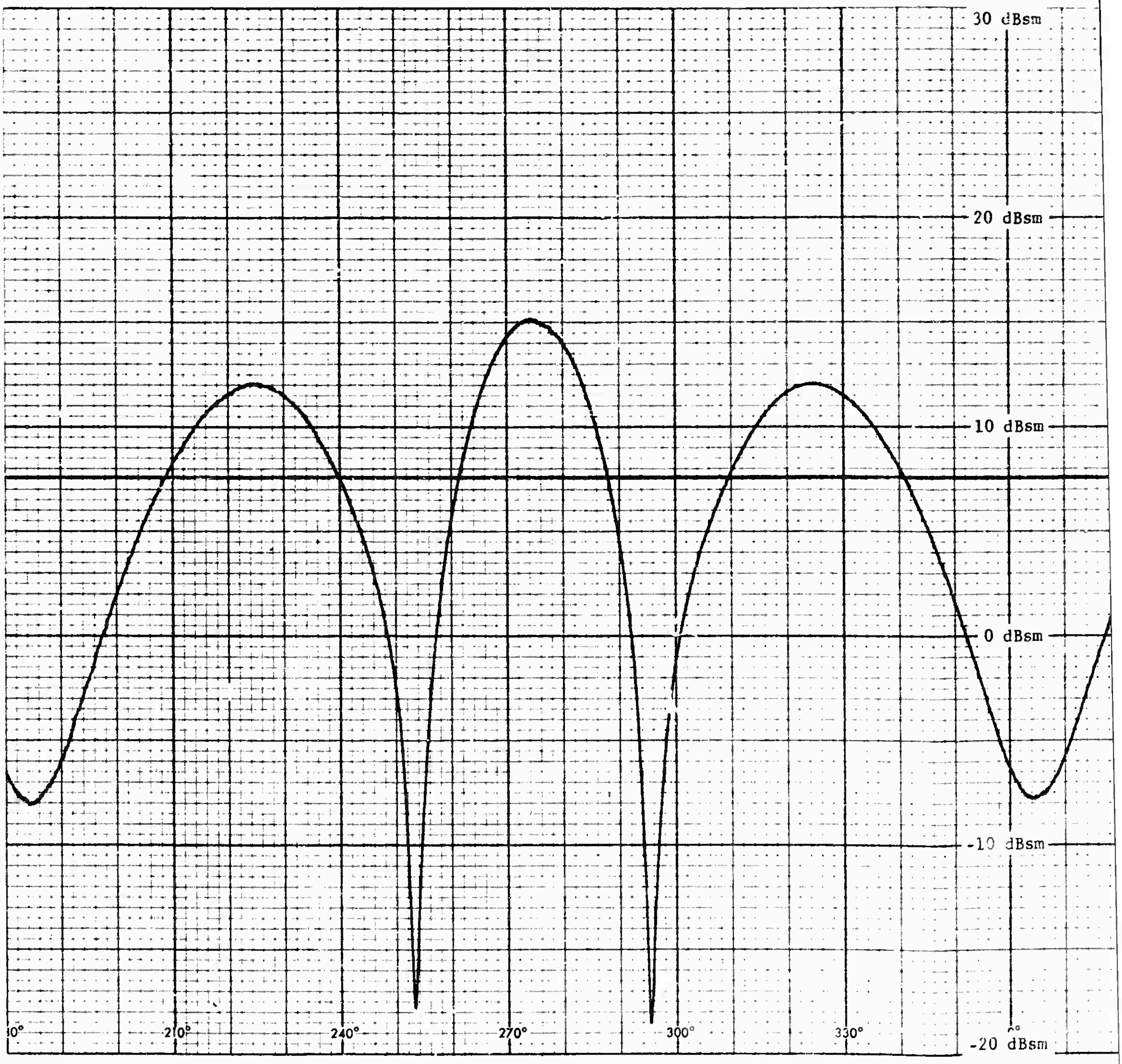


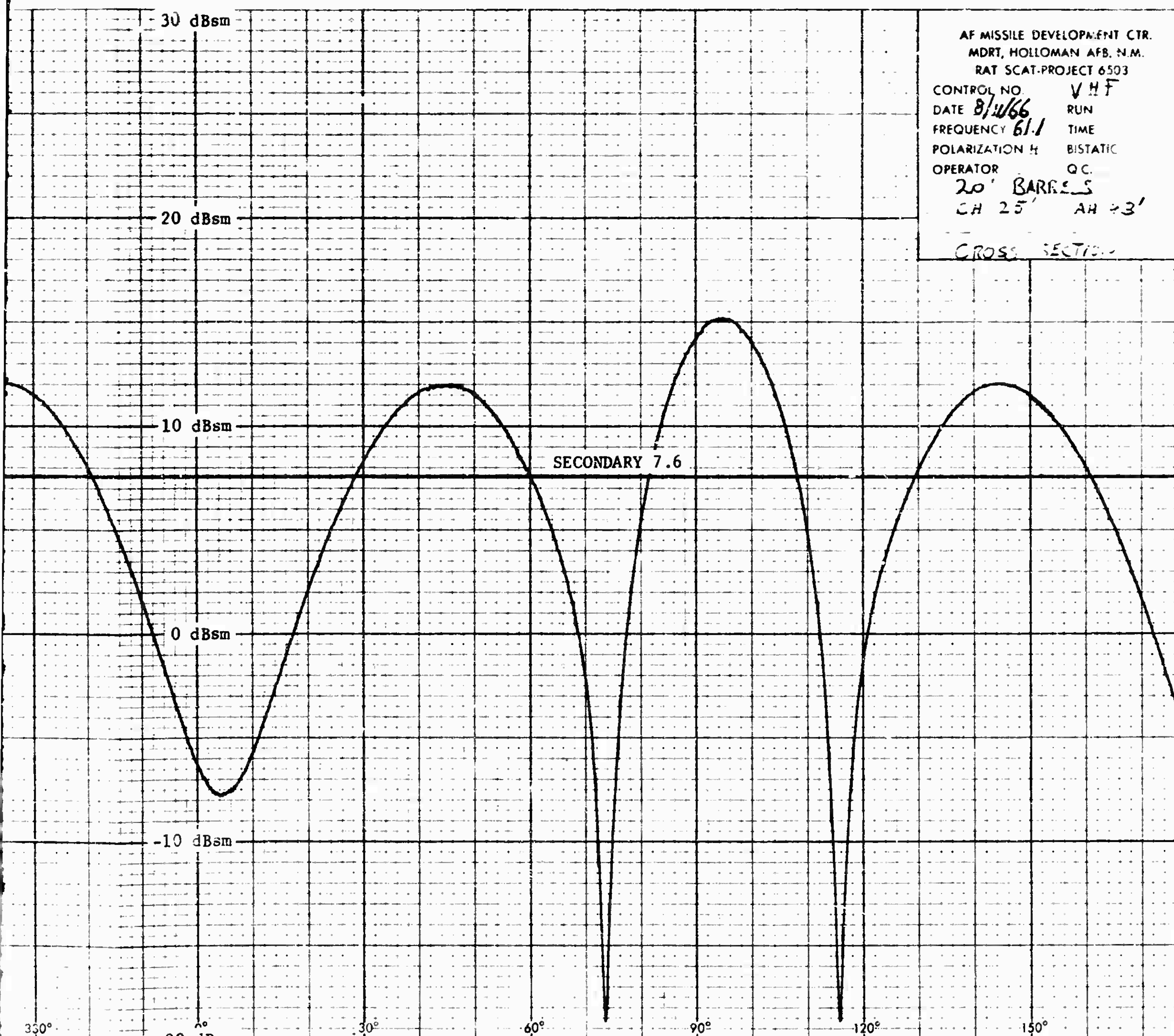
Figure 64



0°
72°
144°
SECONDARY 180°
216°
288°
360°
0°
30°
60°
90°
120°
150°
AF MISSILE DEVELOPMENT CTR.
MDRT, HOLLOMAN AFB, N.M.
RAT SCAT-PROJECT 6503
CONTROL NO. UHF
DATE 8-6-66 RUN
FREQUENCY 145.5 TIME
POLARIZATION V BISTATIC °
OPERATOR Q.C.
40'
CH 65' AH 48'
PHASE
IF CANCELLATION USED


30 dBsm
20 dBsm
10 dBsm
0 dBsm
-10 dBsm
-20 dBsm
210°
240°
270°
300°
330°

2



AF MISSILE DEVELOPMENT CTR.
MDRT, HOLLOMAN AFB, N.M.
RAT SCAT-PROJECT 6503
CONTROL NO. VHF
DATE 8/11/66
RUN
FREQUENCY 61.1
TIME
POLARIZATION H
BISTATIC
OPERATOR
Q.C.
20' BARRELS
CH 25'
AH 23'
CROSS SECTION
30 dBsm
20 dBsm
10 dBsm
SECONDARY 7.6
0 dBsm
-10 dBsm
-20 dBsm
330°
0°
30°
60°
90°
120°
150°

Figure

Figure 66

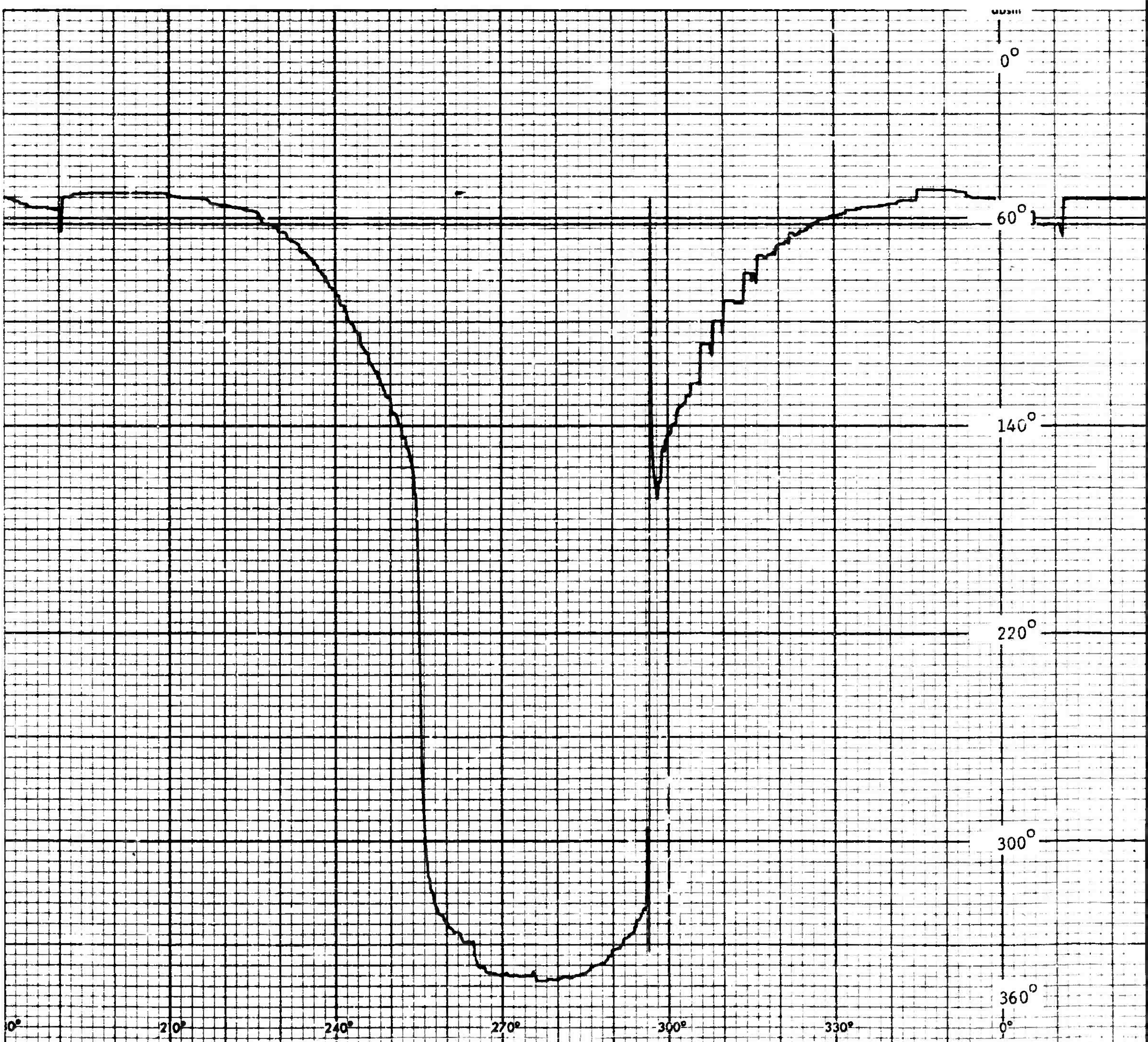
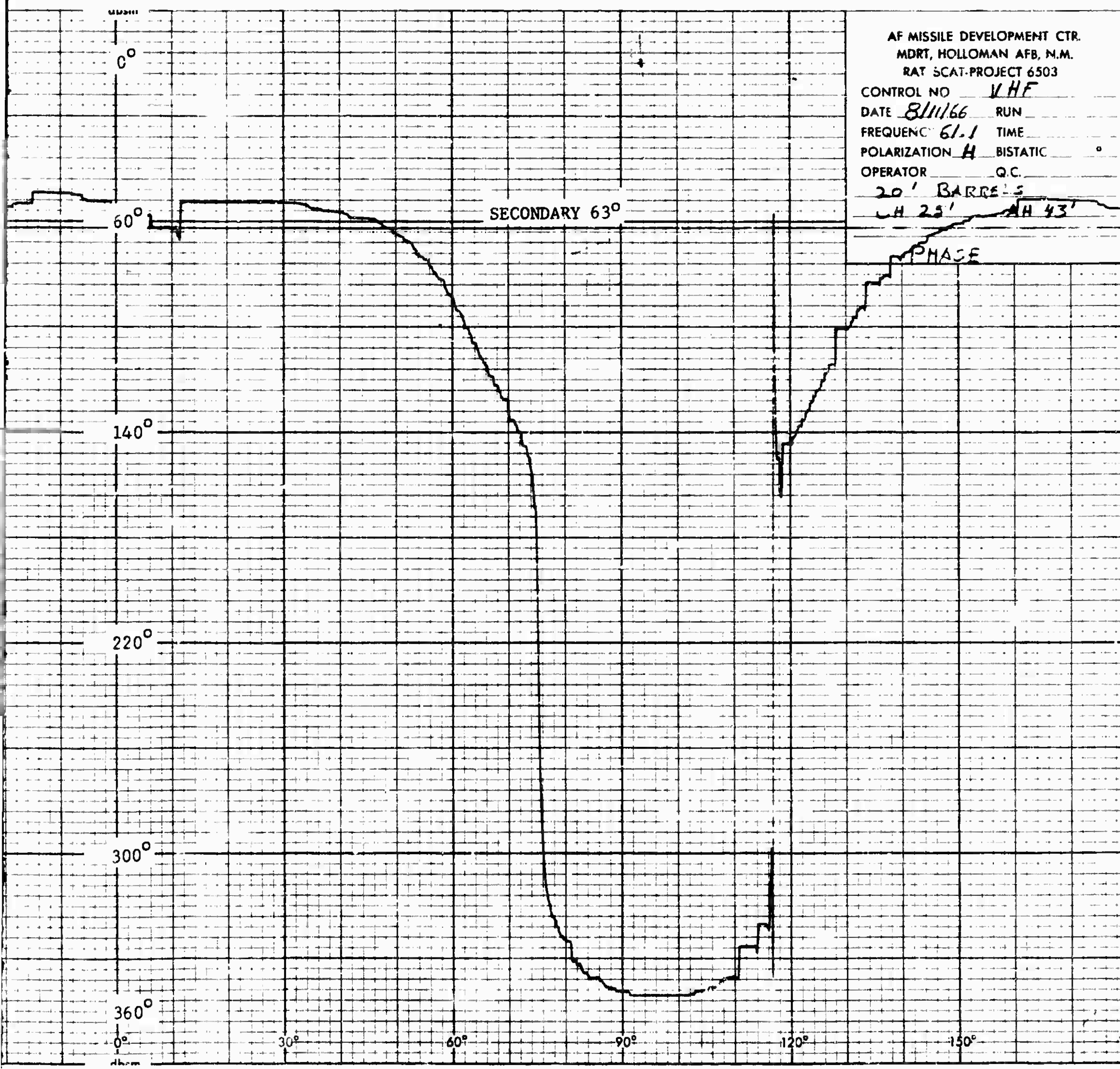
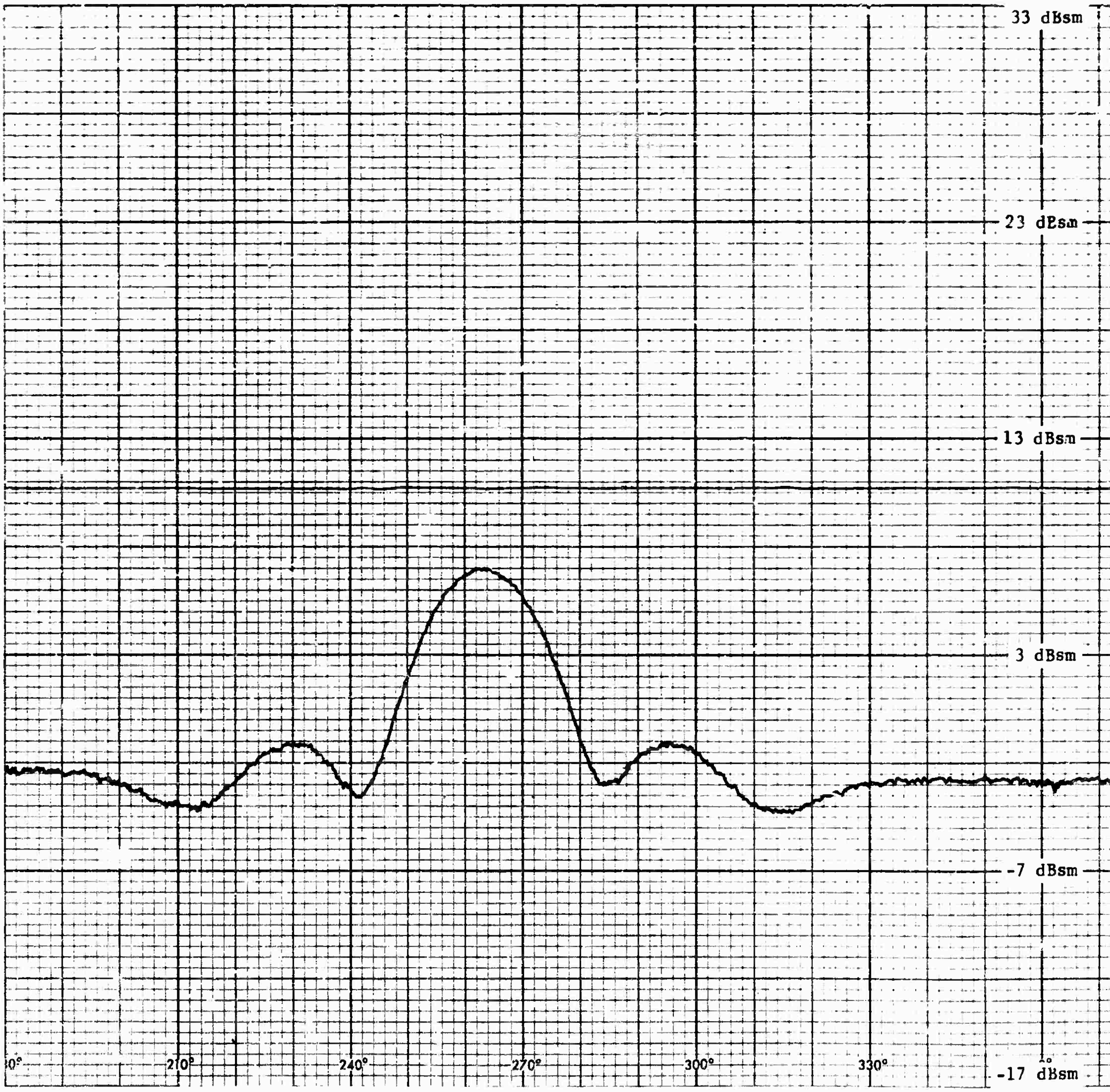


Figure 66


AF MISSILE DEVELOPMENT CTR.
MDRT, HOLLOMAN AFB, N.M.
RAT SCAT-PROJECT 6503
CONTROL NO VHF
DATE 8/11/66 RUN
FREQUENC 61.1 TIME
POLARIZATION H BISTATIC
OPERATOR Q.C.
20' BARRELS
CH 25' AH 43'
PHASE
SECONDARY 63°
0°
60°
140°
220°
300°
360°
0°
30°
60°
90°
120°
150°

2



1

2

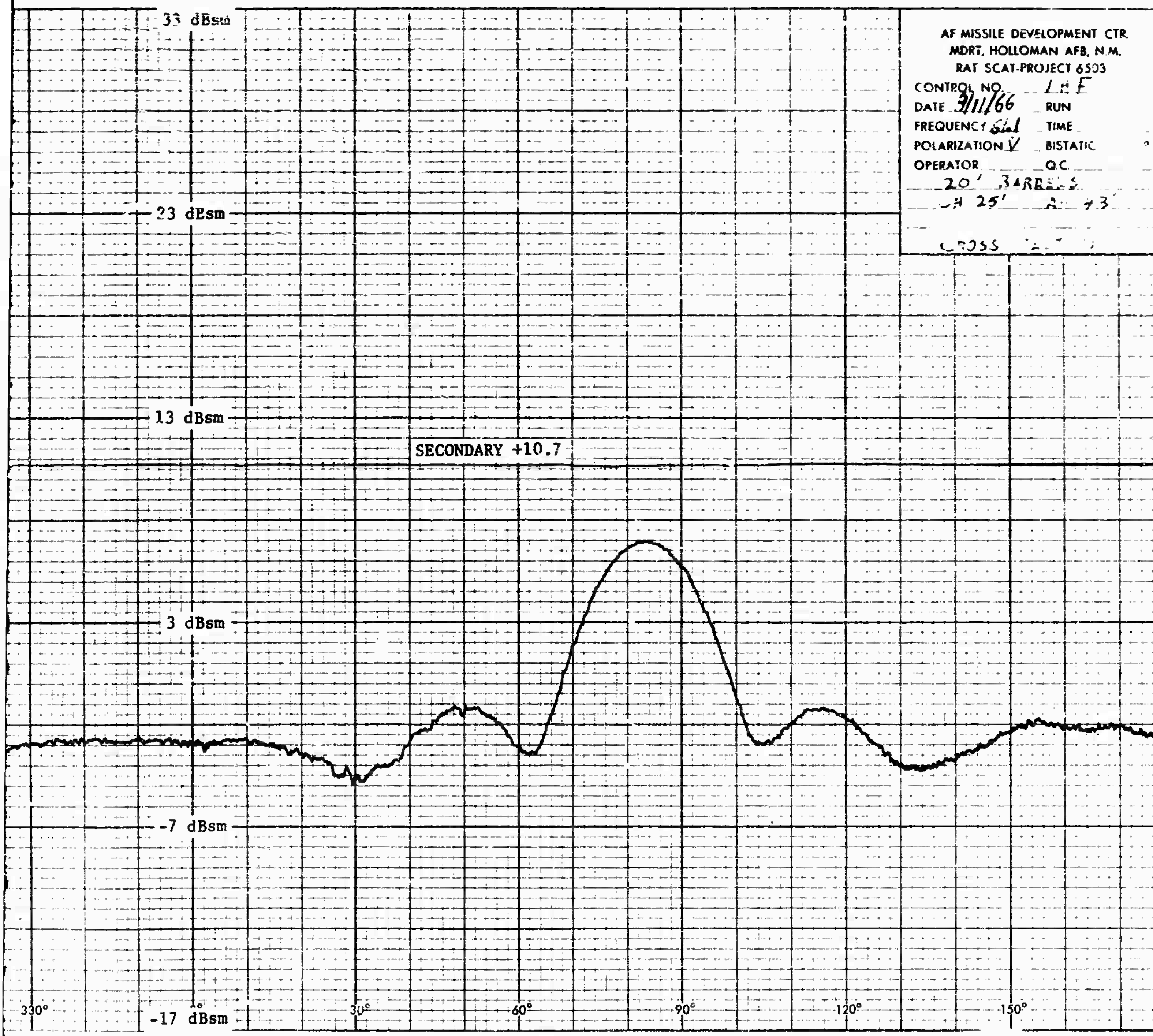

33 dBsm
23 dBsm
13 dBsm
SECONDARY +10.7
3 dBsm
-7 dBsm
-17 dBsm
330°
30°
60°
90°
120°
150°
AF MISSILE DEVELOPMENT CTR
MDRT, HOLLOMAN AFB, N.M.
RAT SCAT-PROJECT 6503
CONTROL NO.
DATE 3/11/66
RUN
FREQUENCY
TIME
POLARIZATION V
BISTATIC
OPERATOR
Q.C.
20' BARRELS

Figure 6

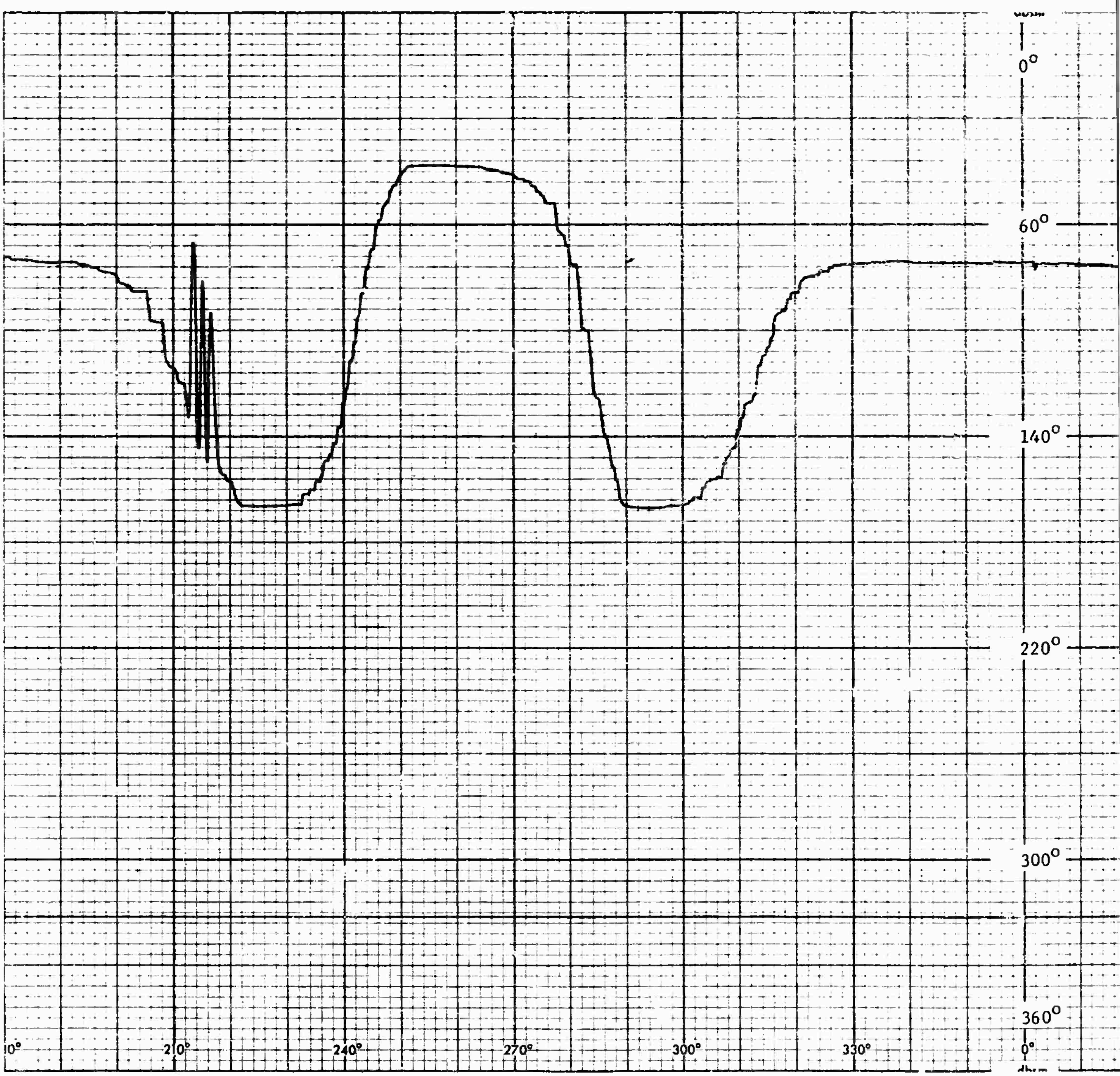
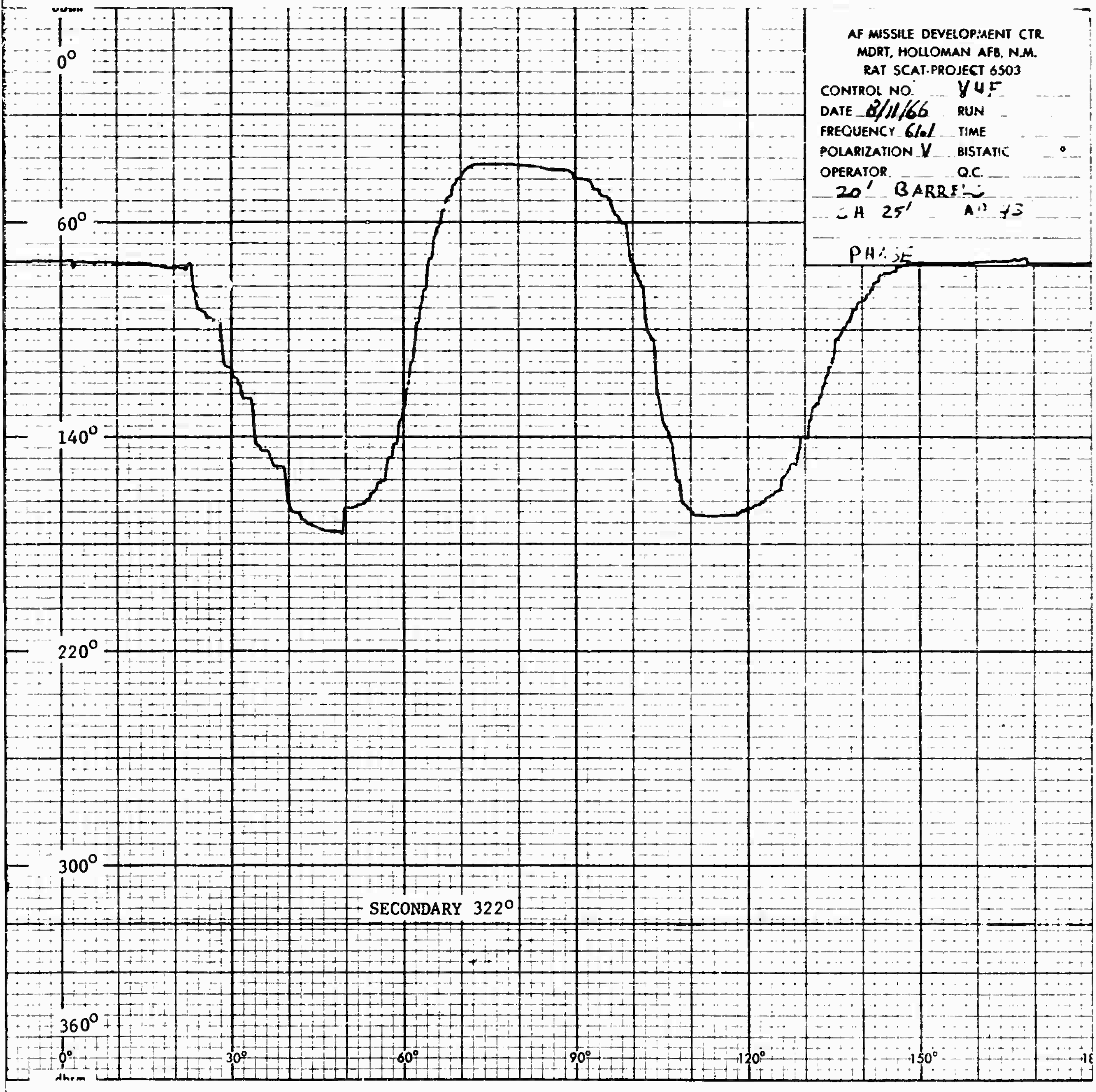
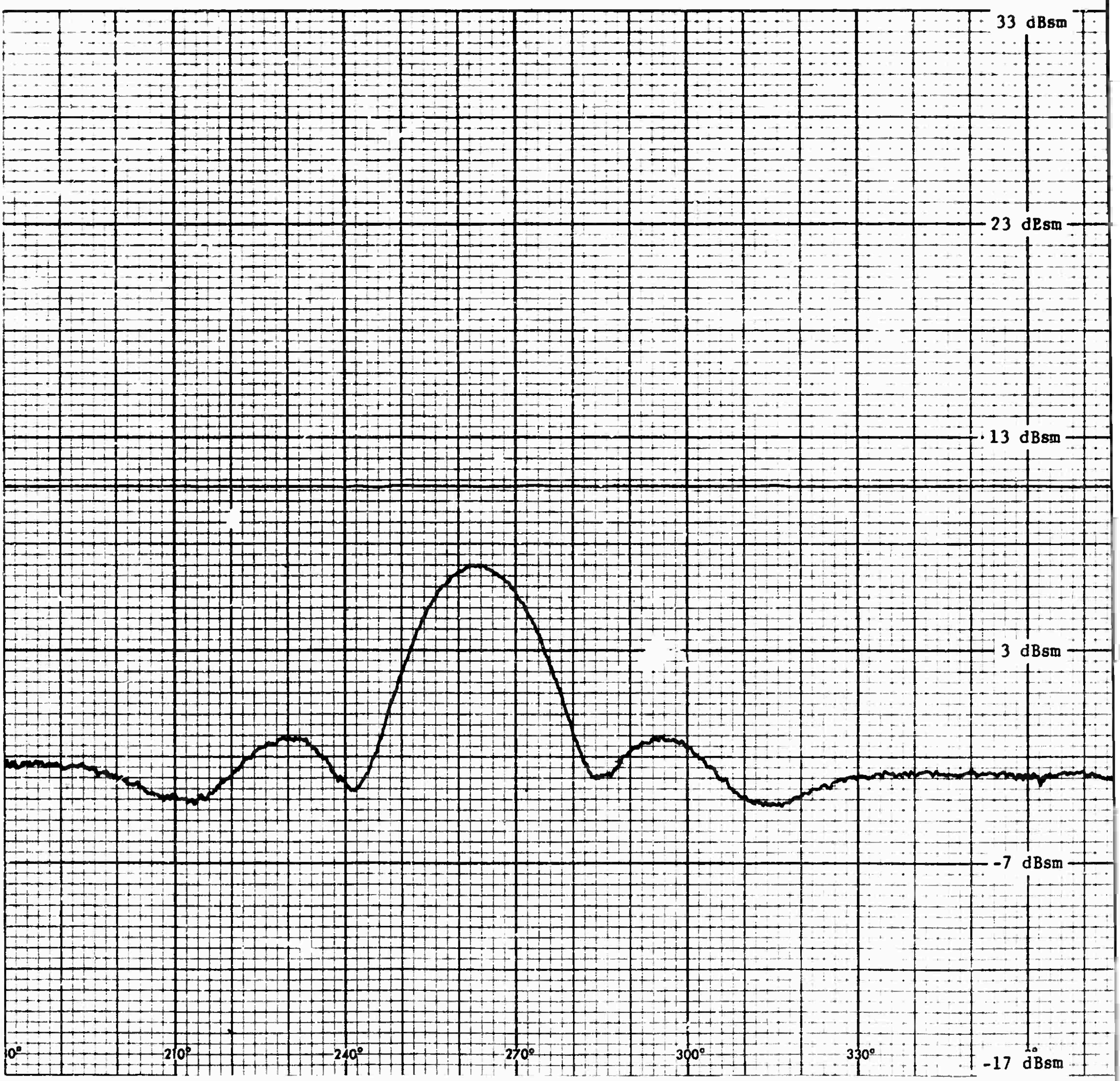


Figure 68


AF MISSILE DEVELOPMENT CTR.
MDRT, HOLLOMAN AFB, N.M.
RAT SCAT-PROJECT 6503
CONTROL NO. V4F
DATE 8/11/66
RUN
FREQUENCY 6.1
TIME
POLARIZATION V
BISTATIC °
OPERATOR
Q.C.
20' BARREL
PHASE
0°
60°
140°
220°
300°
360°
SECONDARY 322°
0°
30°
60°
90°
120°
150°

2



1

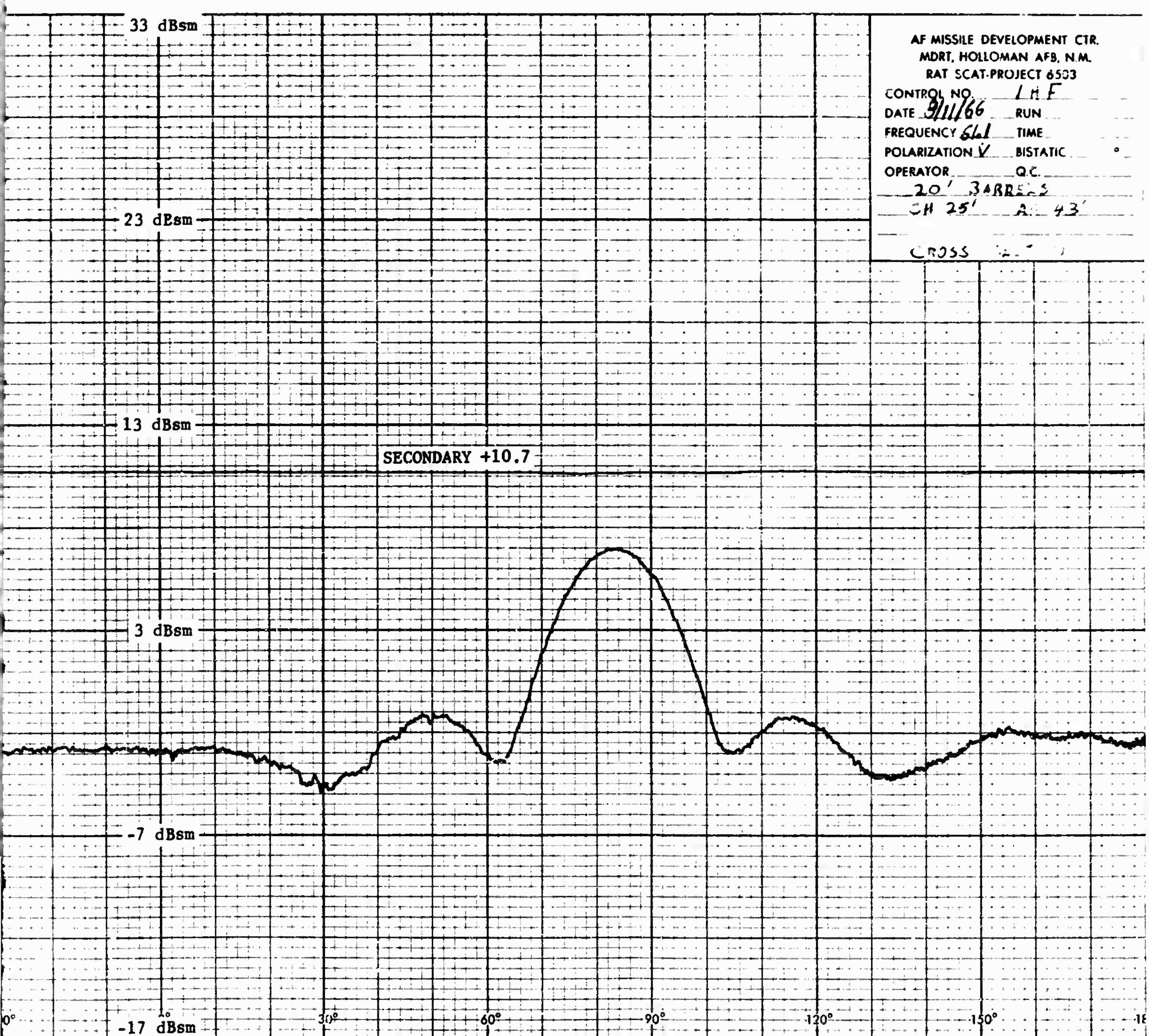

33 dBsm
23 dBsm
13 dBsm
SECONDARY +10.7
3 dBsm
-7 dBsm
-17 dBsm
0°
30°
60°
90°
120°
150°
AF MISSILE DEVELOPMENT CTR.
MDRT, HOLLOMAN AFB, N.M.
RAT SCAT-PROJECT 6503
CONTROL NO. LHF
DATE 9/11/66 RUN
FREQUENCY 661 TIME
POLARIZATION V BISTATIC °
OPERATOR Q.C.
20' BARRELS
CROSS

Figure 67


20 dBsm
10 dBsm
0 dBsm
-10 dBsm
-20 dBsm
-30 dBsm
210°
240°
270°
300°
330°

1

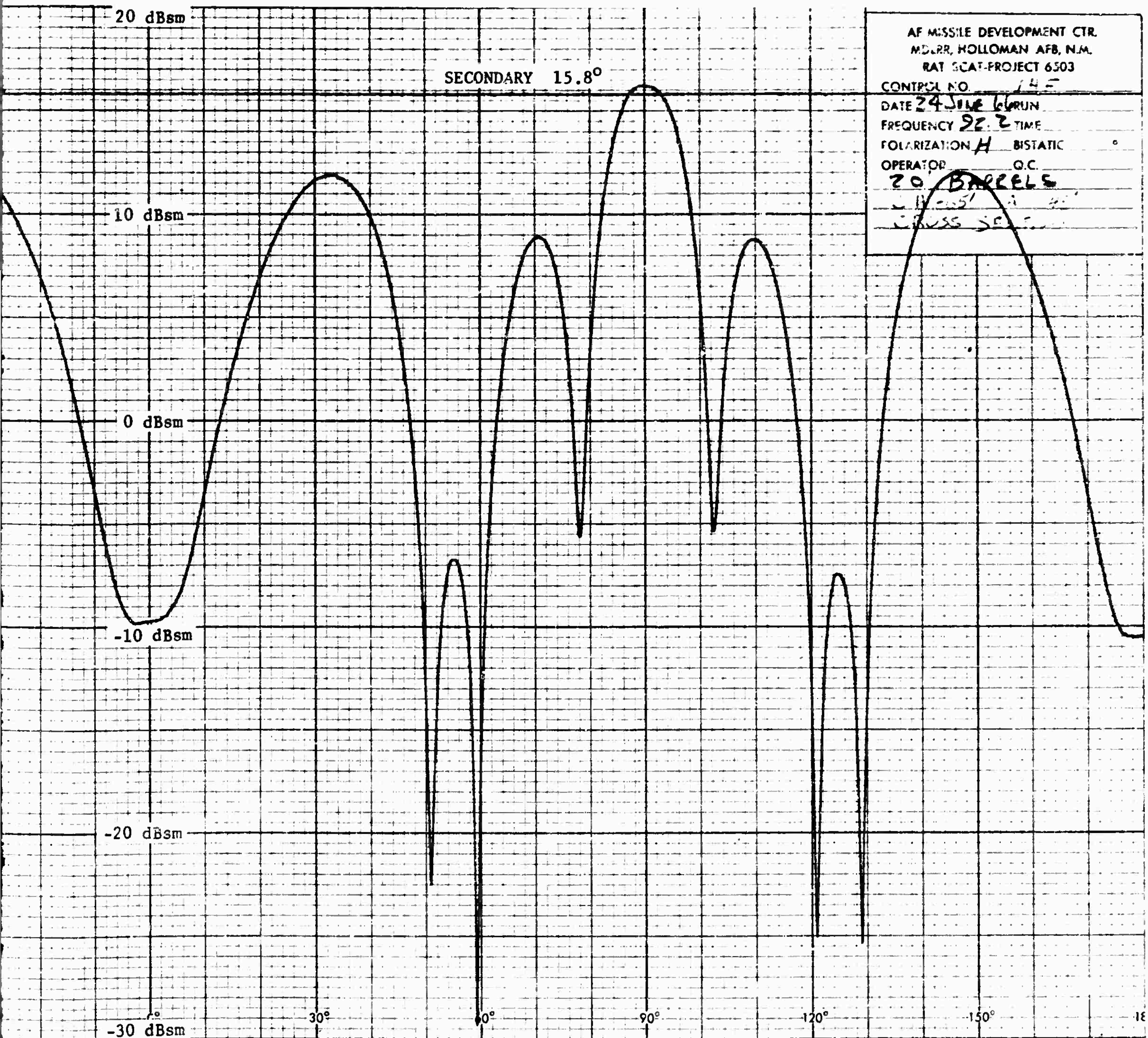

20 dBsm
10 dBsm
0 dBsm
-10 dBsm
-20 dBsm
-30 dBsm
SECONDARY 15.8°
30°
60°
90°
120°
150°
AF MISSILE DEVELOPMENT CTR.
HOLLOMAN AFB, N.M.
RAT SCAT-PROJECT 6503
CONTROL NO.
DATE 24 June 66 RUN
FREQUENCY 92.2 TIME
POLARIZATION H BISTATIC
OPERATOR Q.C.
20 BARRELS

Figure 69

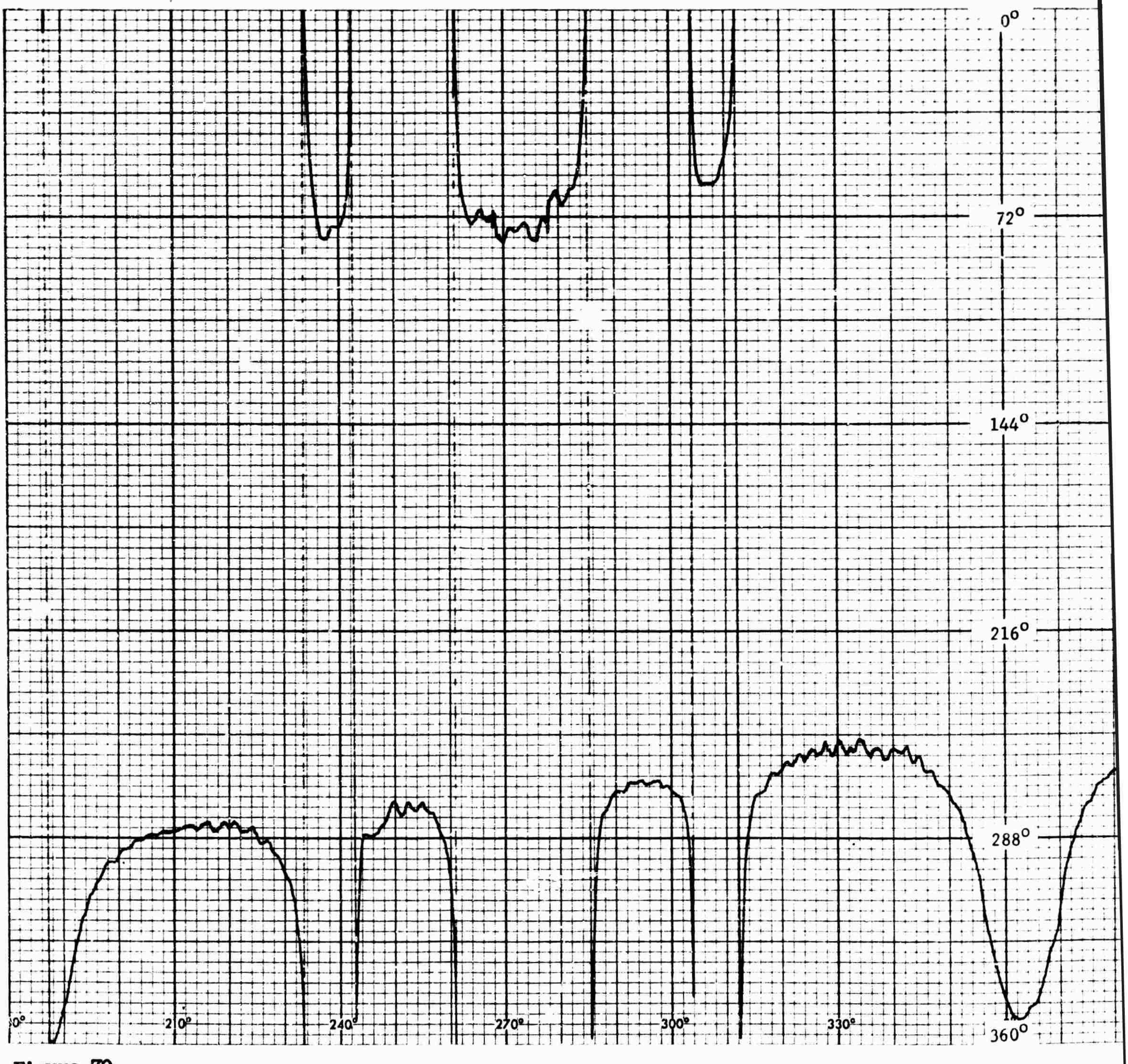
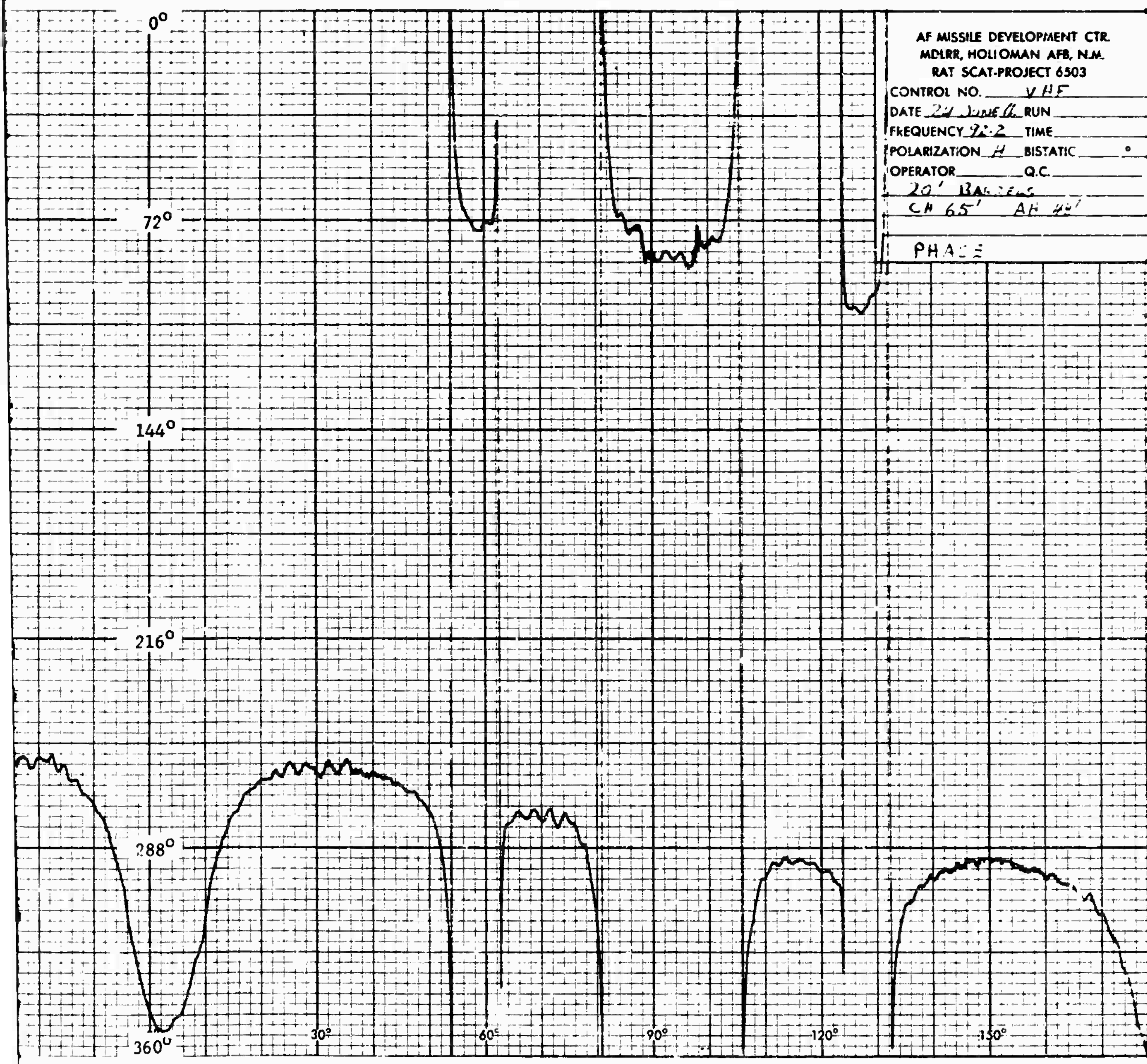
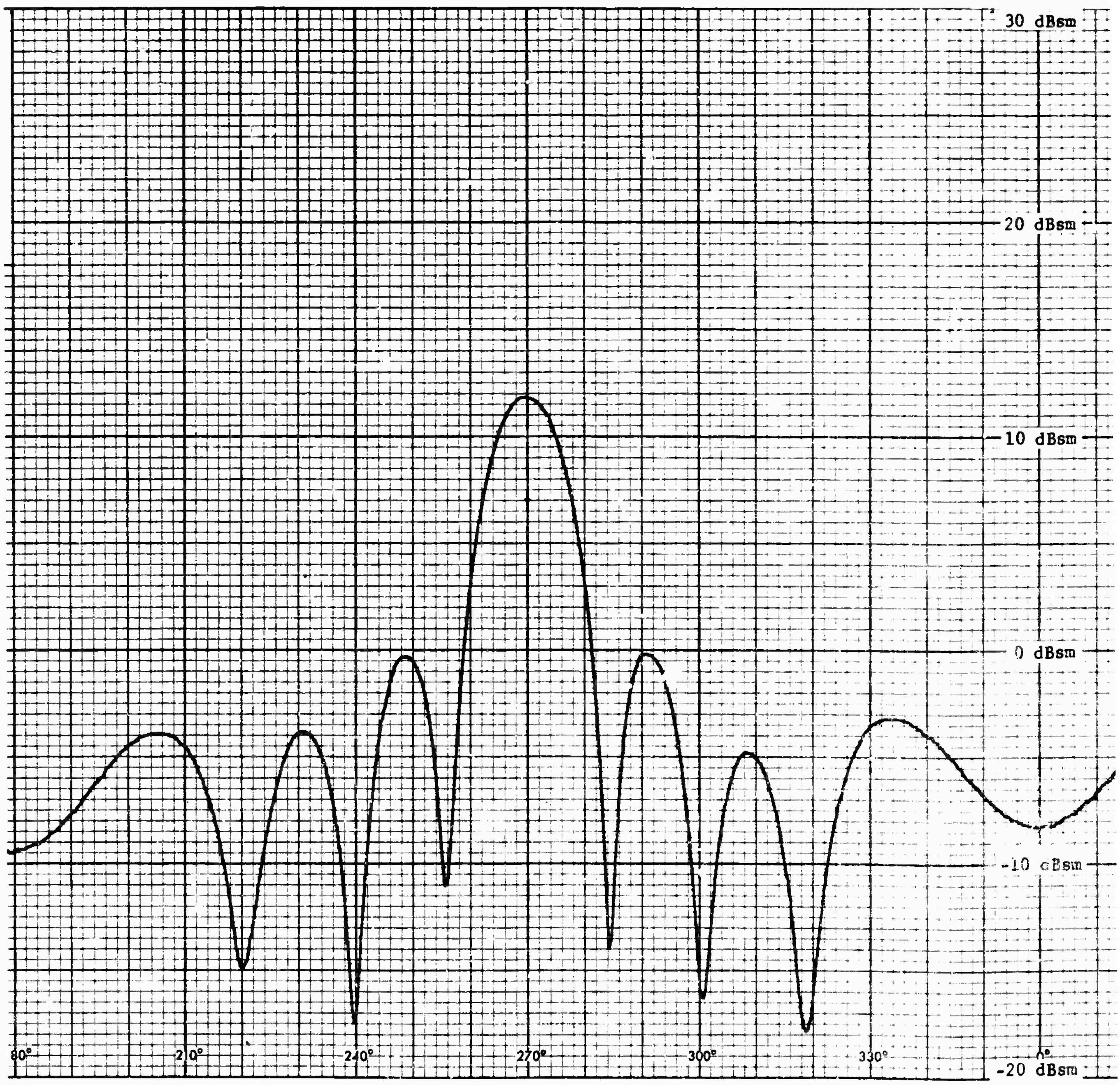


Figure 70


AF MISSILE DEVELOPMENT CTR.
MDLRR, HOLLOMAN AFB, N.M.
RAT SCAT-PROJECT 6503
CONTROL NO. VHF
DATE 24 June 6_ RUN
FREQUENCY 92.2 TIME
POLARIZATION H BISTATIC °
OPERATOR Q.C.
CH 65' AH 4_'
PHASE
0°
72°
144°
216°
288°
360°
30°
60°
90°
120°
150°

2


30 dBsm
20 dBsm
10 dBsm
0 dBsm
-10 dBsm
-20 dBsm
210°
240°
270°
300°
330°
0°

1

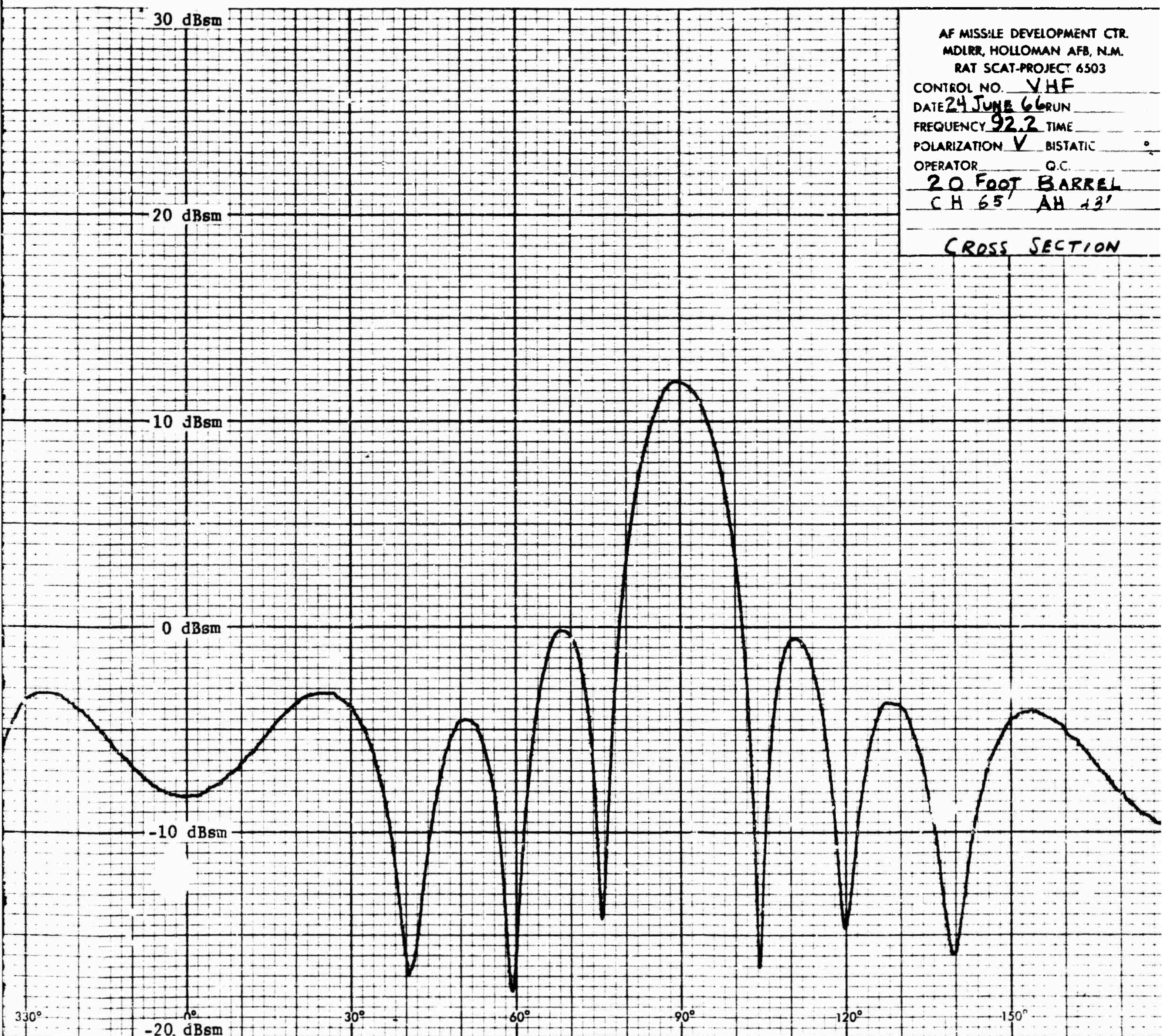

30 dBsm
20 dBsm
10 dBsm
0 dBsm
-10 dBsm
-20. dBsm
330°
0°
30°
60°
90°
120°
150°
AF MISSILE DEVELOPMENT CTR.
MDLRR, HOLLOMAN AFB, N.M.
RAT SCAT-PROJECT 6503
CONTROL NO. VHF
DATE 24 JUNE 66 RUN
FREQUENCY 92.2 TIME
POLARIZATION V BISTATIC
OPERATOR Q.C.
20 FOOT BARREL
CH 65' AH 13'
CROSS SECTION

Figure 7I

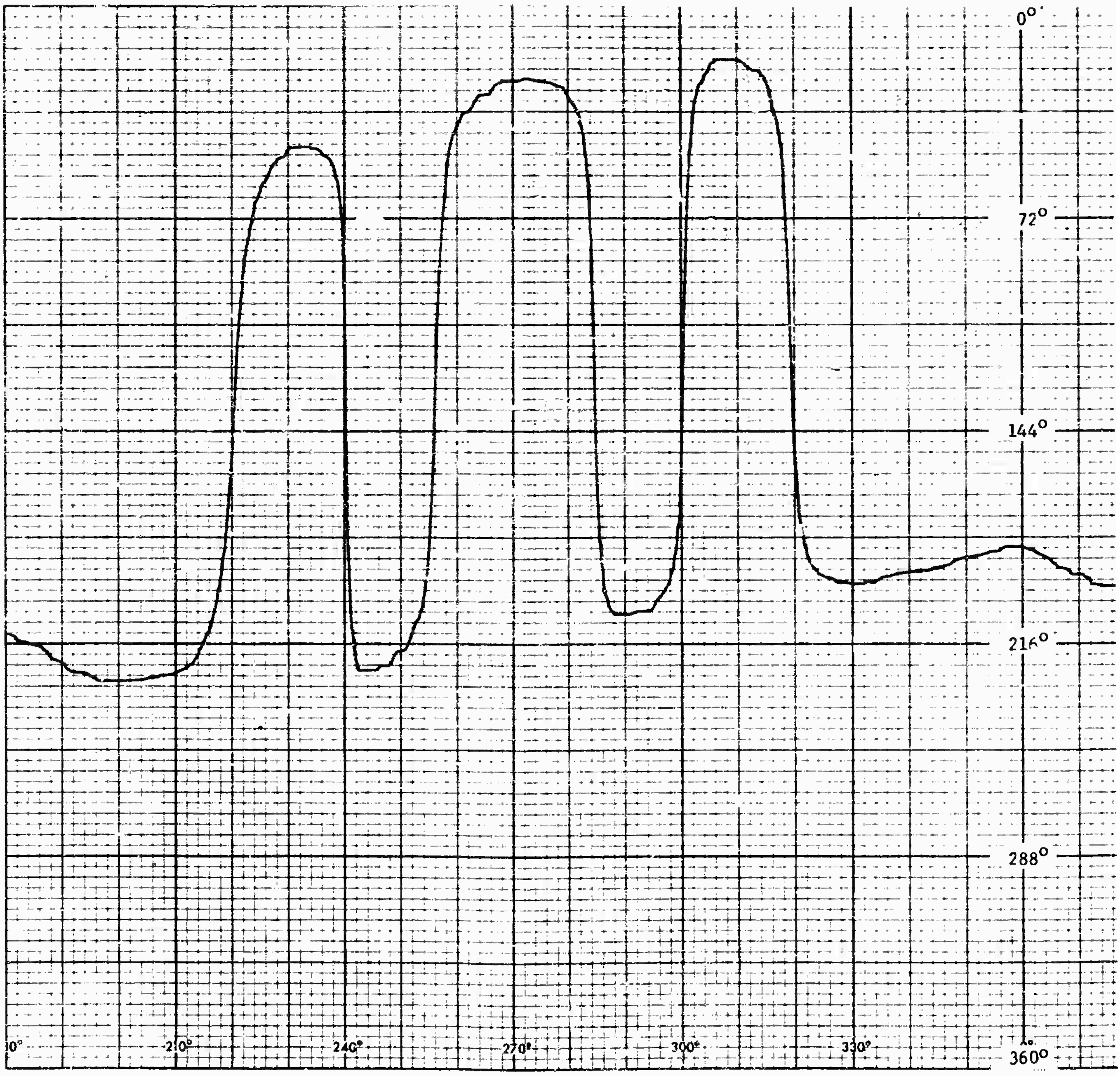
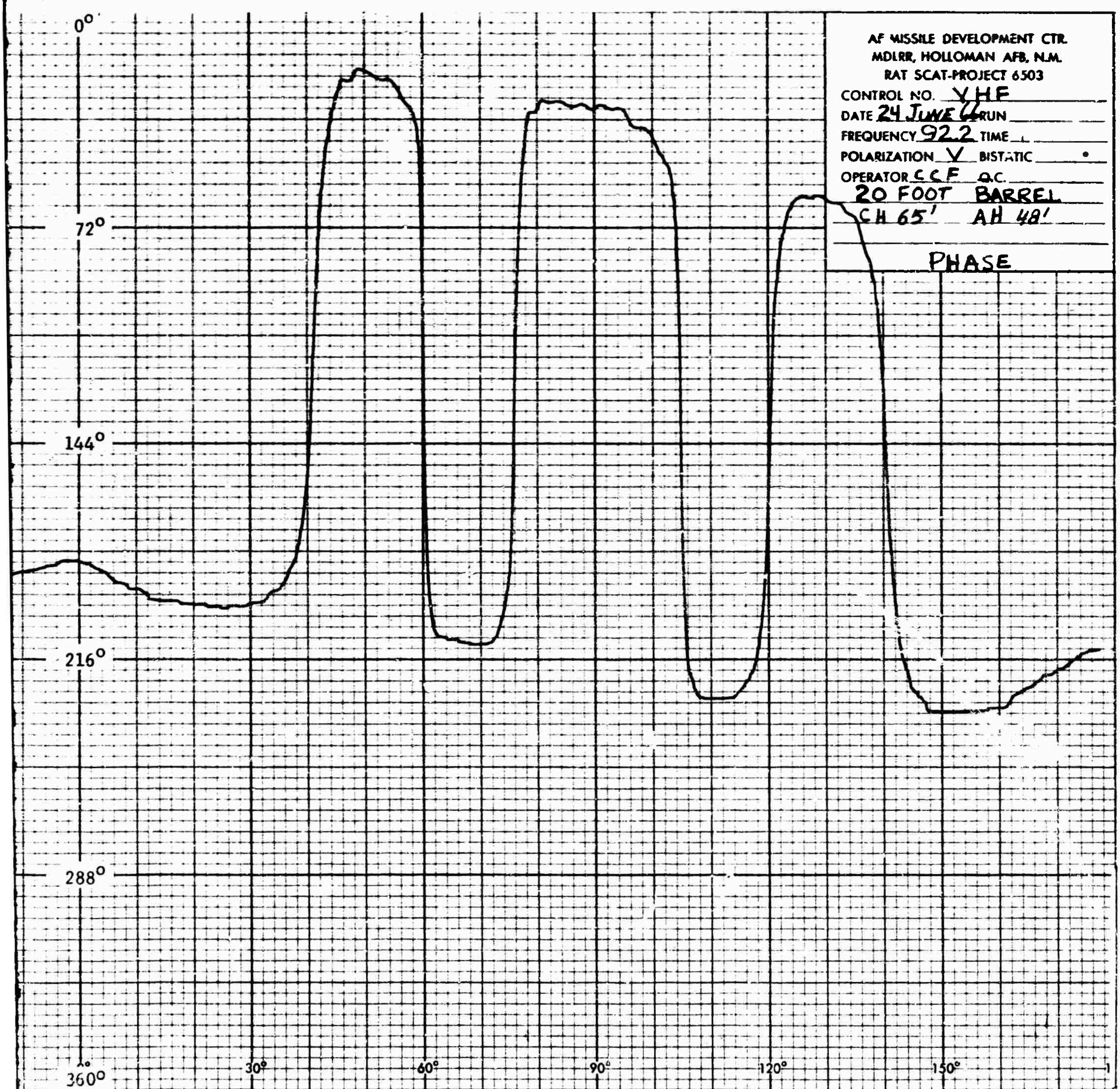
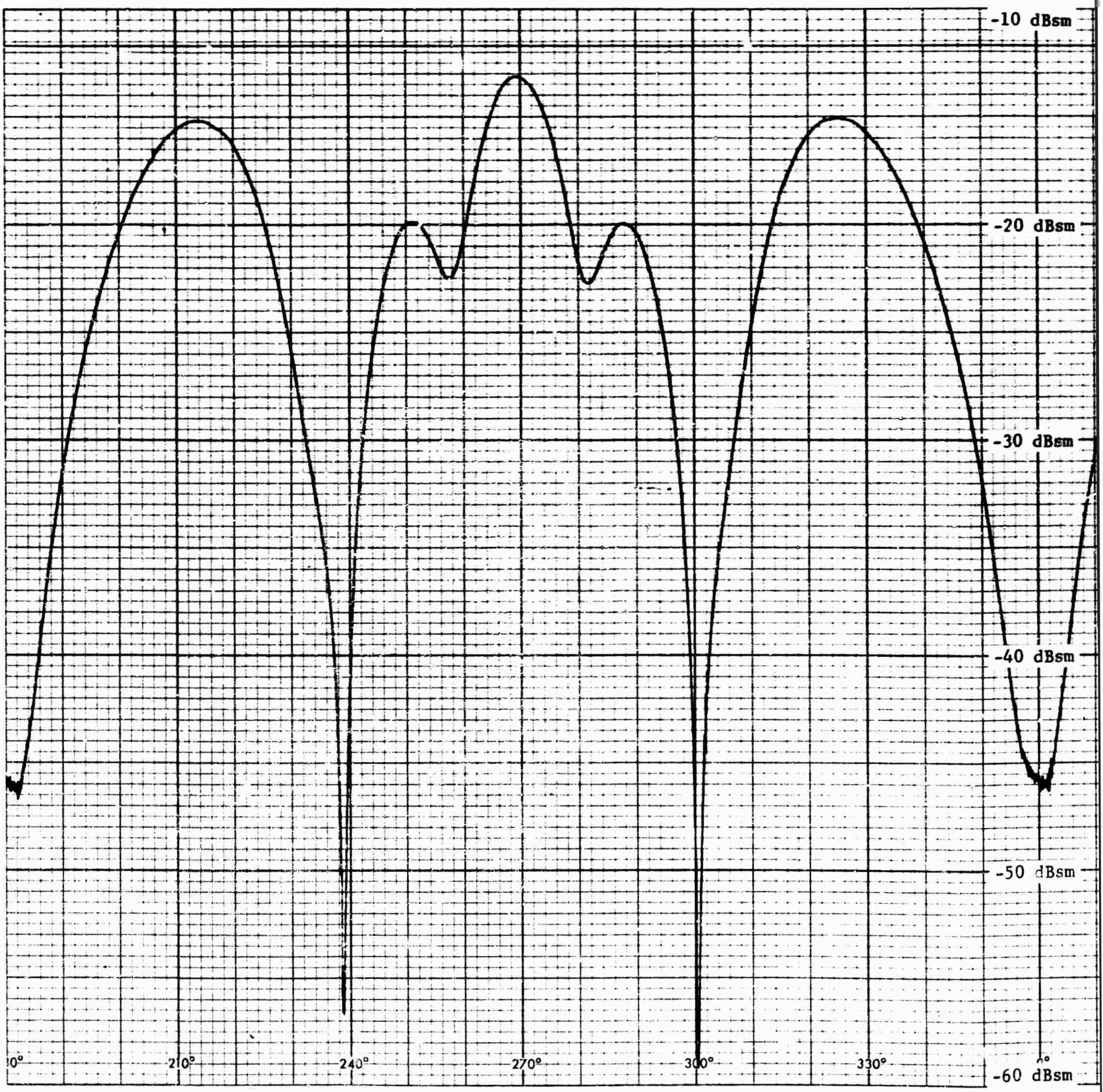


Figure 72



0°
72°
144°
216°
288°
360°
30°
60°
90°
120°
150°
AF MISSILE DEVELOPMENT CTR.
MDLRR, HOLLOMAN AFB, N.M.
RAT SCAT-PROJECT 6503
CONTROL NO. VHF
DATE 24 JUNE 66 RUN
FREQUENCY 92.2 TIME
POLARIZATION V BISTATIC
OPERATOR CCF Q.C.
20 FOOT BARREL
CH 65' AH 48'
PHASE

2



-10 dBsm
-20 dBsm
-30 dBsm
-40 dBsm
-50 dBsm
-60 dBsm
210°
240°
270°
300°
330°

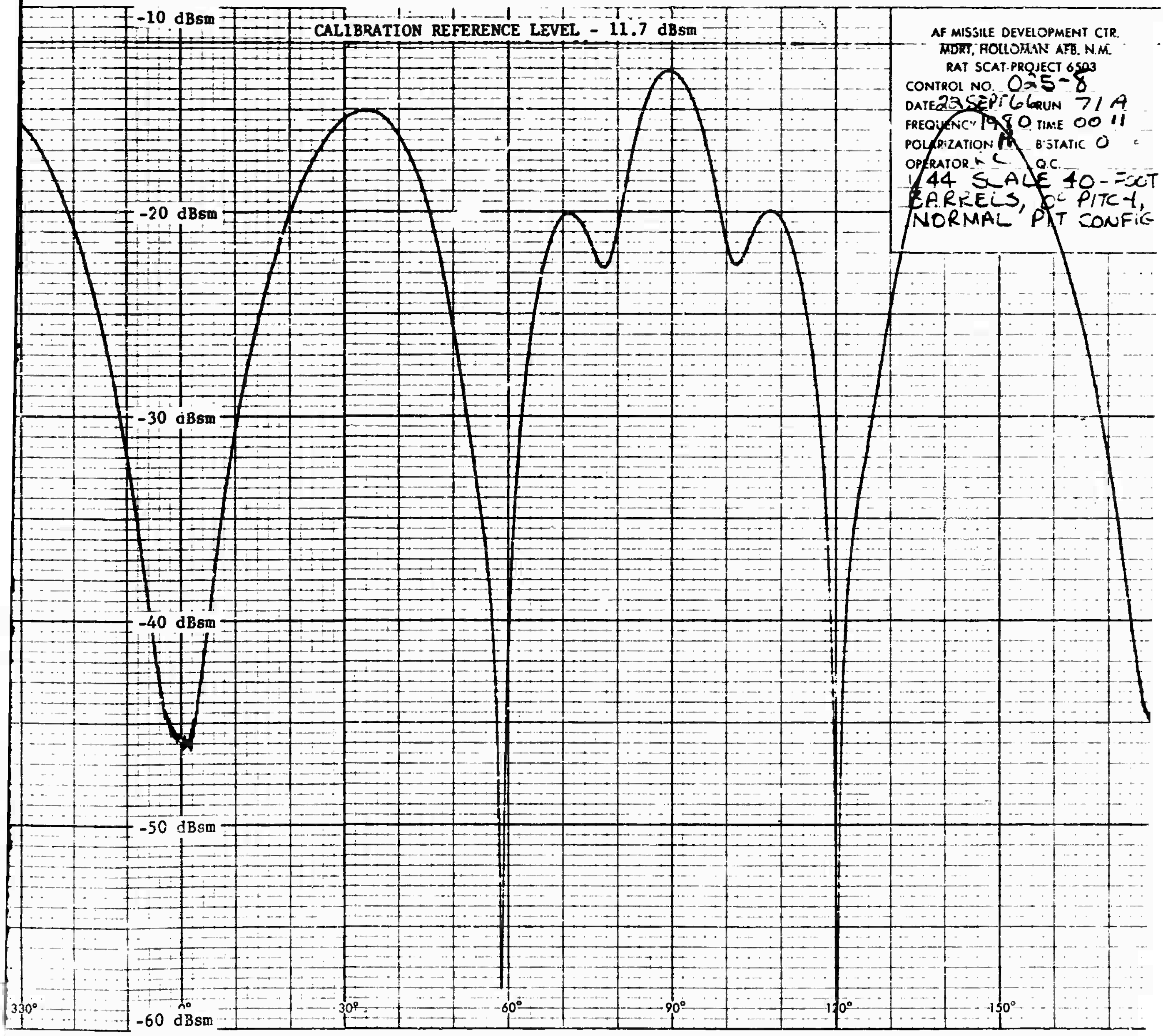

CALIBRATION REFERENCE LEVEL - 11.7 dBsm
-10 dBsm
-20 dBsm
-30 dBsm
-40 dBsm
-50 dBsm
-60 dBsm
330°
0°
30°
60°
90°
120°
150°
AF MISSILE DEVELOPMENT CTR.
MDRT, HOLLOMAN AFB, N.M.
RAT SCAT PROJECT 6503
CONTROL NO. 025-8
DATE 23SEPT66 RUN 71A
FREQUENCY 1980 TIME 0011
POLARIZATION H BISTATIC 0
OPERATOR Q.C.
1/44 SCALE 40-FOOT BARRELS, 0° PITCH, NORMAL PIT CONFIG

Figure 7

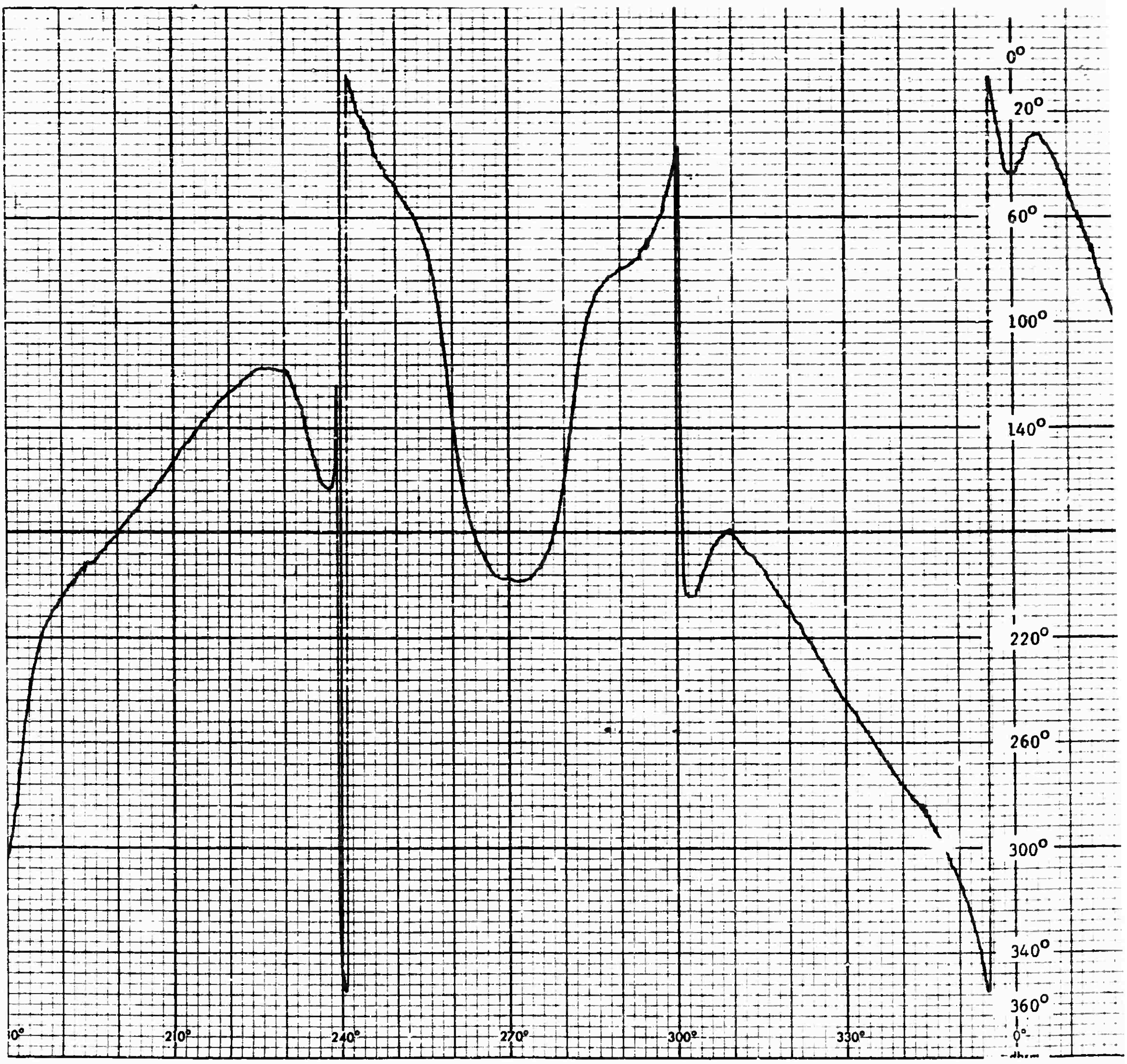
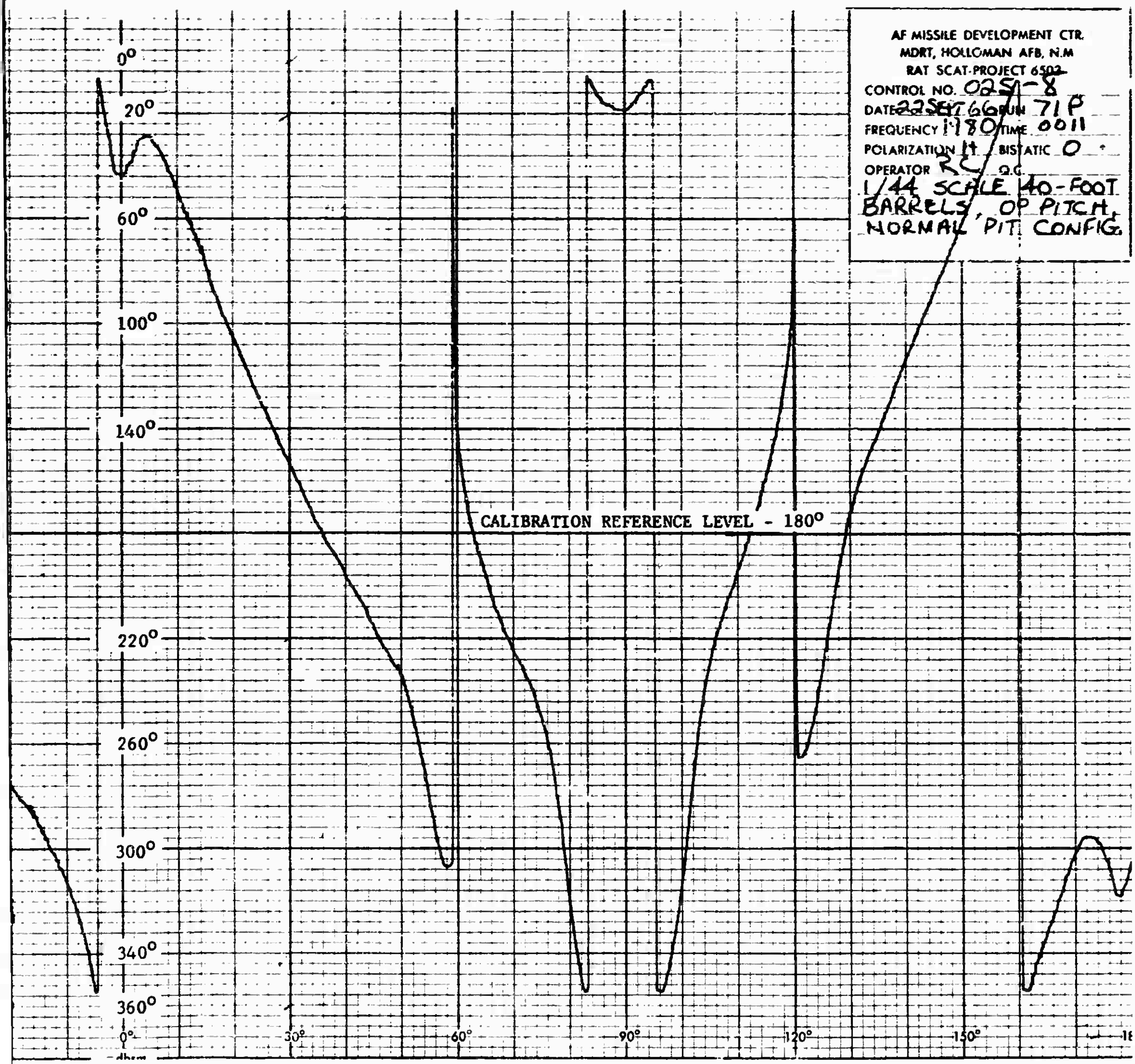
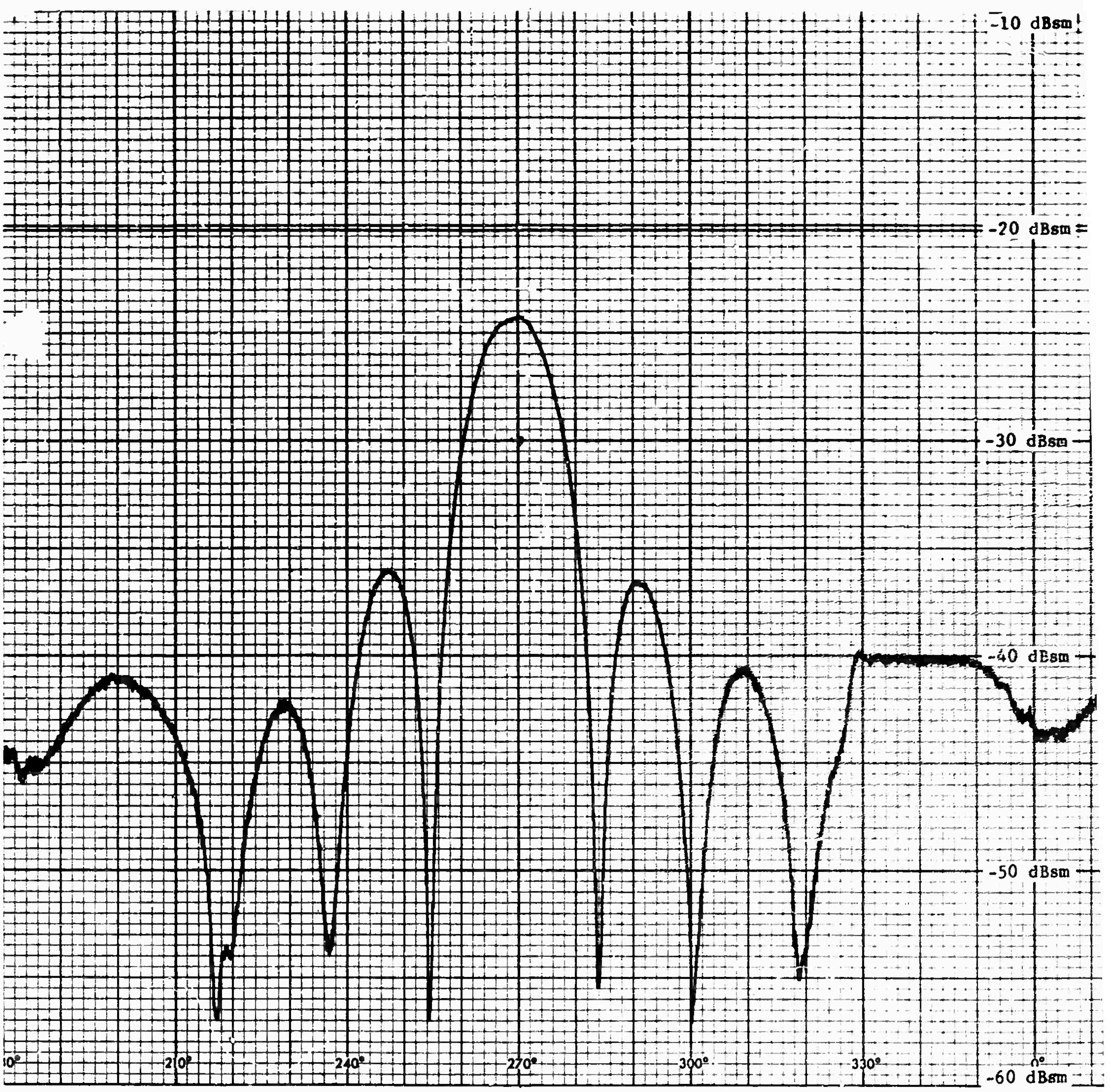


Figure 74


AF MISSILE DEVELOPMENT CTR.
MDRT, HOLLOMAN AFB, N.M
RAT SCAT-PROJECT 6503
CONTROL NO. 025-8
DATE 22 SEPT 66 RUN 71P
FREQUENCY 1.180 TIME 0011
POLARIZATION H BISTATIC 0
OPERATOR RC Q.C.
1/44 SCALE 40-FOOT BARRELS, OP PITCH, NORMAL PIT CONFIG.
CALIBRATION REFERENCE LEVEL - 180°
0°
20°
60°
100°
140°
220°
260°
300°
340°
360°
0°
30°
60°
90°
120°
150°
dbm


-10 dBsm
-20 dBsm
-30 dBsm
-40 dBsm
-50 dBsm
-60 dBsm
210°
240°
270°
300°
330°
0°

1

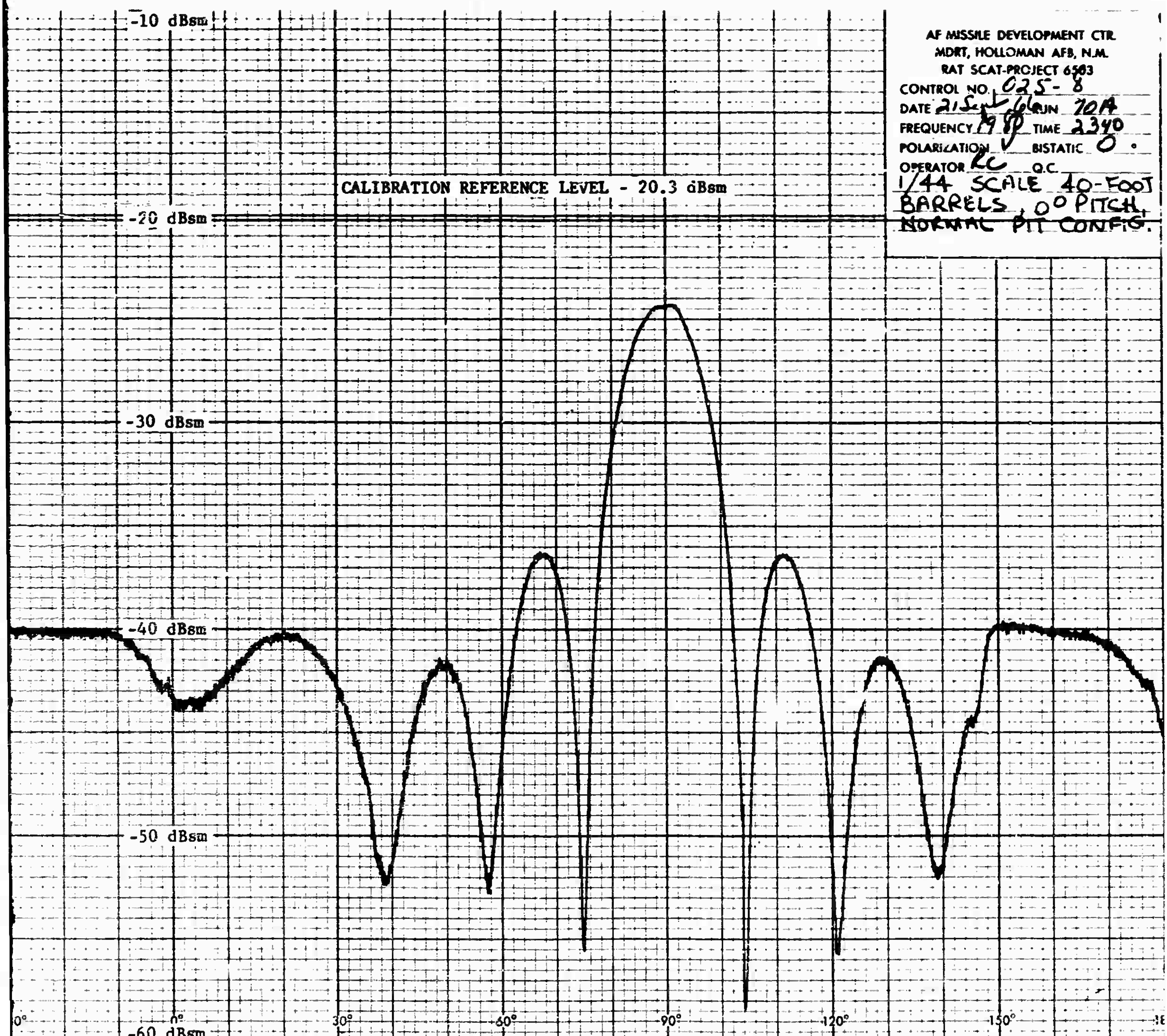

-10 dBsm
-20 dBsm
-30 dBsm
-40 dBsm
-50 dBsm
-60 dBsm
CALIBRATION REFERENCE LEVEL - 20.3 dBsm
0°
30°
60°
90°
120°
150°
AF MISSILE DEVELOPMENT CTR.
MDRT, HOLLOMAN AFB, N.M.
RAT SCAT-PROJECT 6563
CONTROL NO. 025-8
DATE 21 Sept 66 RUN 70A
TIME 2340
POLARIZATION V BISTATIC 0°
OPERATOR RC Q.C.
1/44 SCALE 40-FOOT BARRELS, 0° PITCH, NORMAL PIT CONFIG.

Figure 75

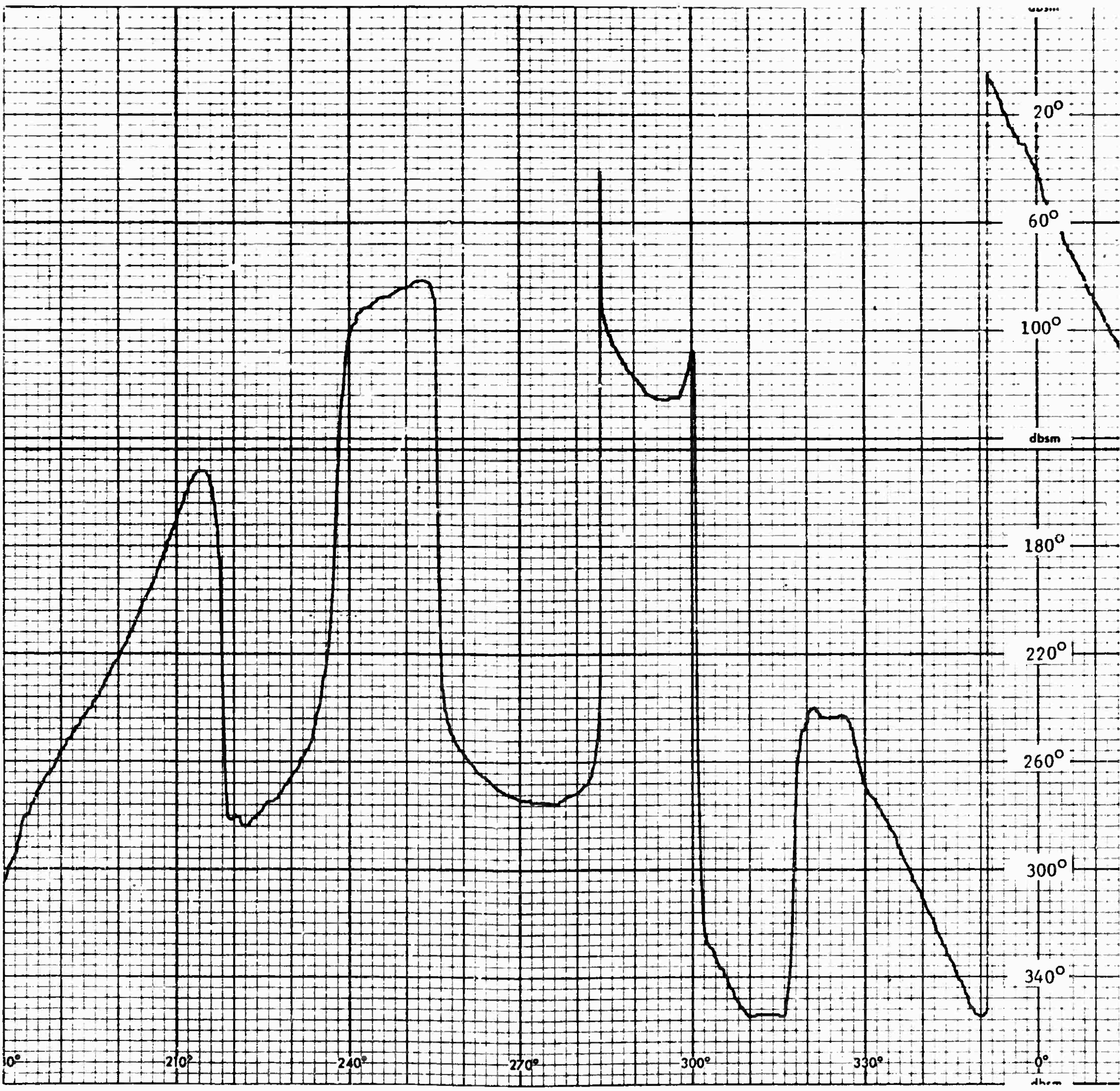
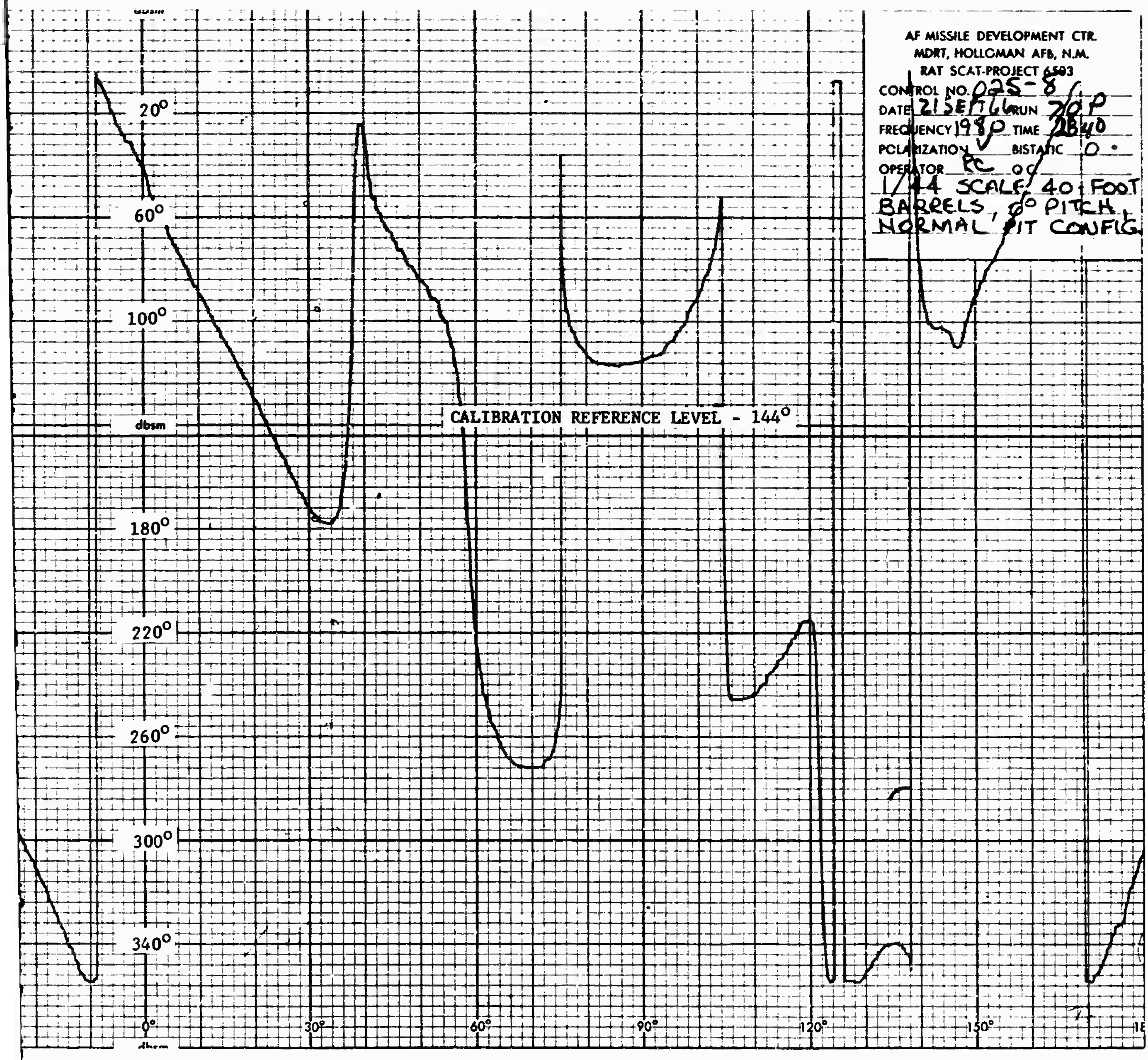
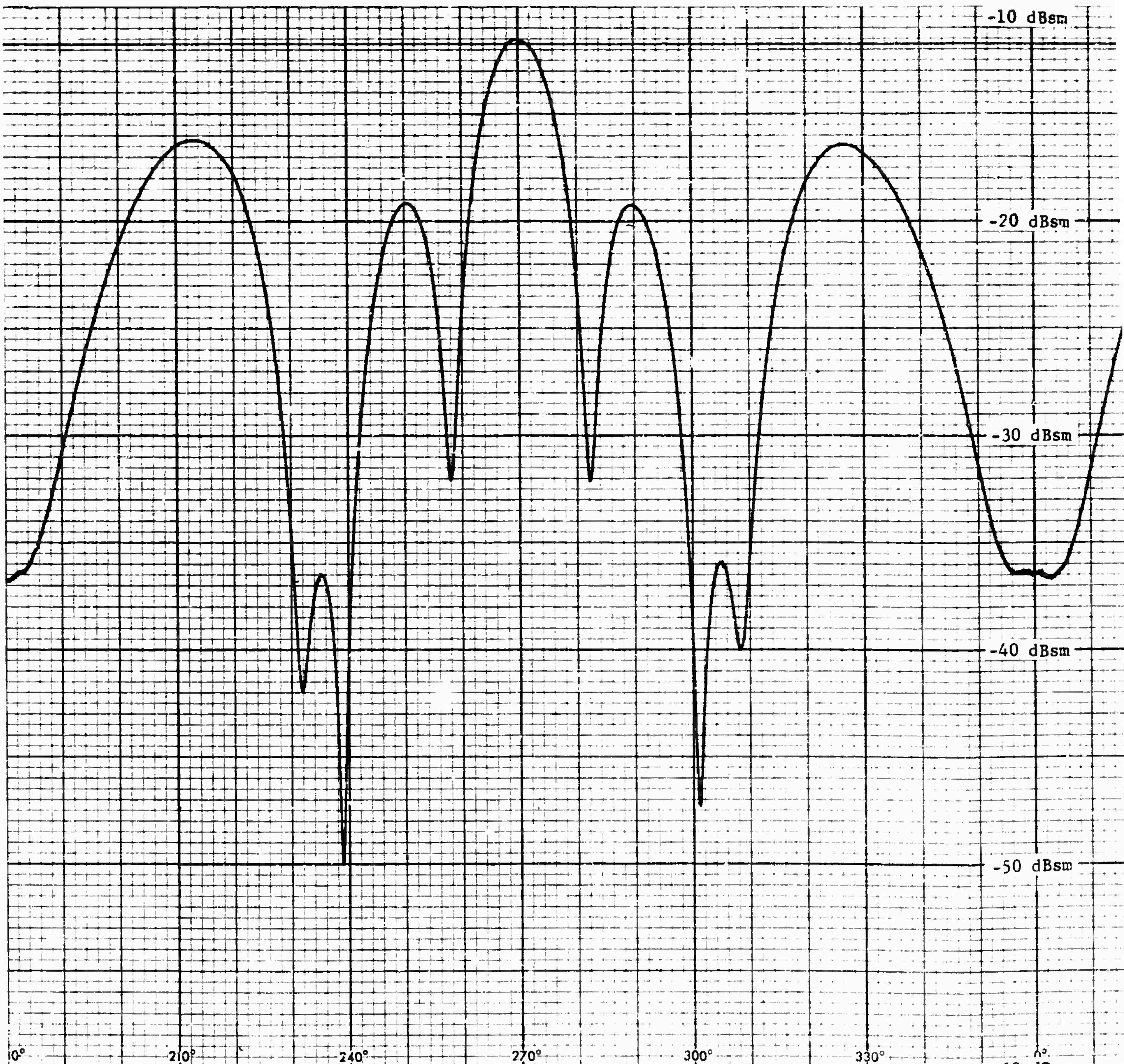


Figure 76

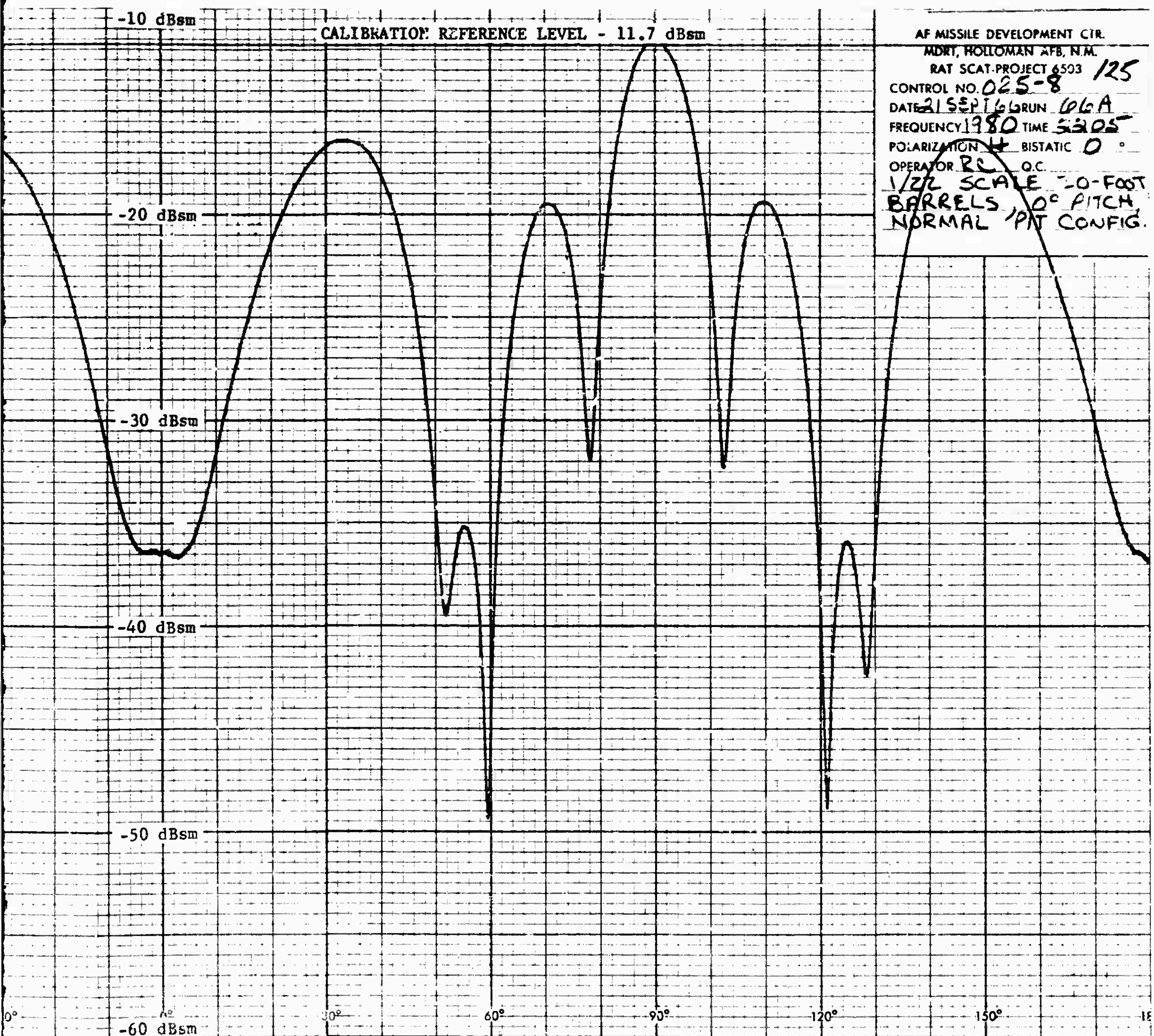

AF MISSILE DEVELOPMENT CTR.
MDRT, HOLLOMAN AFB, N.M.
RAT SCAT-PROJECT 6503
CONTROL NO. 025-8
DATE 21 SEPT 66 RUN 70P
FREQUENCY 1980 TIME 2840
POLARIZATION V BISTATIC 0°
OPERATOR RC QC
1/144 SCALE 40 FOOT
BARRELS, 0° PITCH,
NORMAL PIT CONFIG.
CALIBRATION REFERENCE LEVEL - 144°
dbsm
20°
60°
100°
180°
220°
260°
300°
340°
0°
30°
60°
90°
120°
150°

2



-10 dBsm
-20 dBsm
-30 dBsm
-40 dBsm
-50 dBsm
-60 dBsm
210°
240°
270°
300°
330°

1



-10 dBsm
CALIBRATION REFERENCE LEVEL - 11.7 dBsm
-20 dBsm
-30 dBsm
-40 dBsm
-50 dBsm
-60 dBsm
0°
30°
60°
90°
120°
150°
AF MISSILE DEVELOPMENT CTR.
MDRT, HOLLOMAN AFB, N.M.
RAT SCAT-PROJECT 6503 125
CONTROL NO. 025-8
DATE 21 SEPT 66 RUN 66A
FREQUENCY 1980 TIME 5305
POLARIZATION H BISTATIC 0 °
OPERATOR RC Q.C.
1/22 SCALE
BARRELS, 0° PITCH
NORMAL CONFIG.

Figure 77

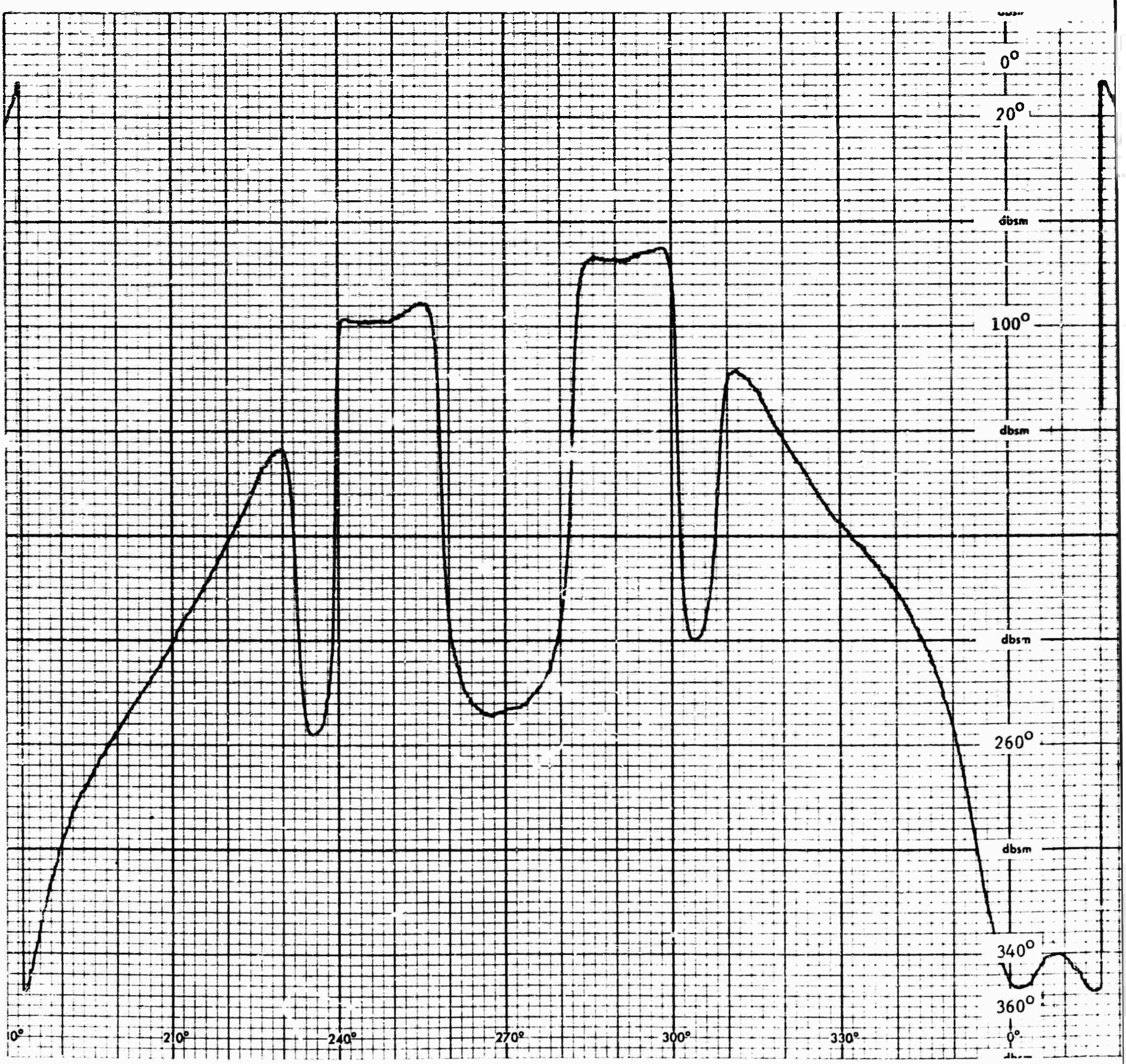
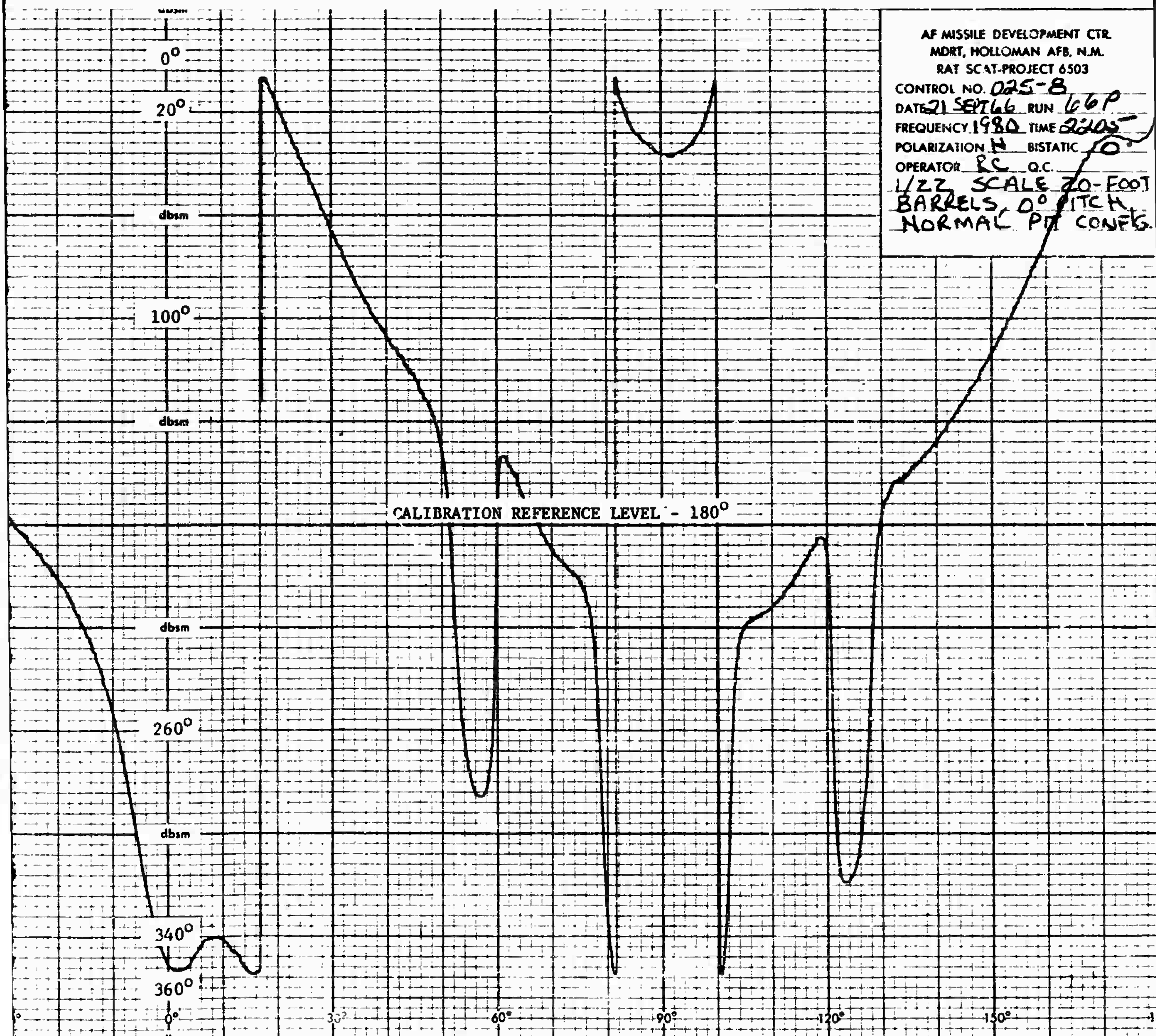


Figure 78


AF MISSILE DEVELOPMENT CTR.
MDRT, HOLLOMAN AFB, N.M.
RAT SCAT-PROJECT 6503
CONTROL NO. 025-8
DATE 21 SEPT 66 RUN 66P
FREQUENCY 1980 TIME 2205
POLARIZATION H BISTATIC 0°
OPERATOR RC Q.C.
1/22 SCALE 20-FOOT BARRELS, 0° PITCH, NORMAL PIT CONFIG.
CALIBRATION REFERENCE LEVEL - 180°
dbsm
0°
20°
100°
260°
340°
360°
30°
60°
90°
120°
150°

2

-10 dBsm
-20 dBsm
-30 dBsm
-40 dBsm
-50 dBsm
-60 dBsm
210°
240°
270°
300°
330°

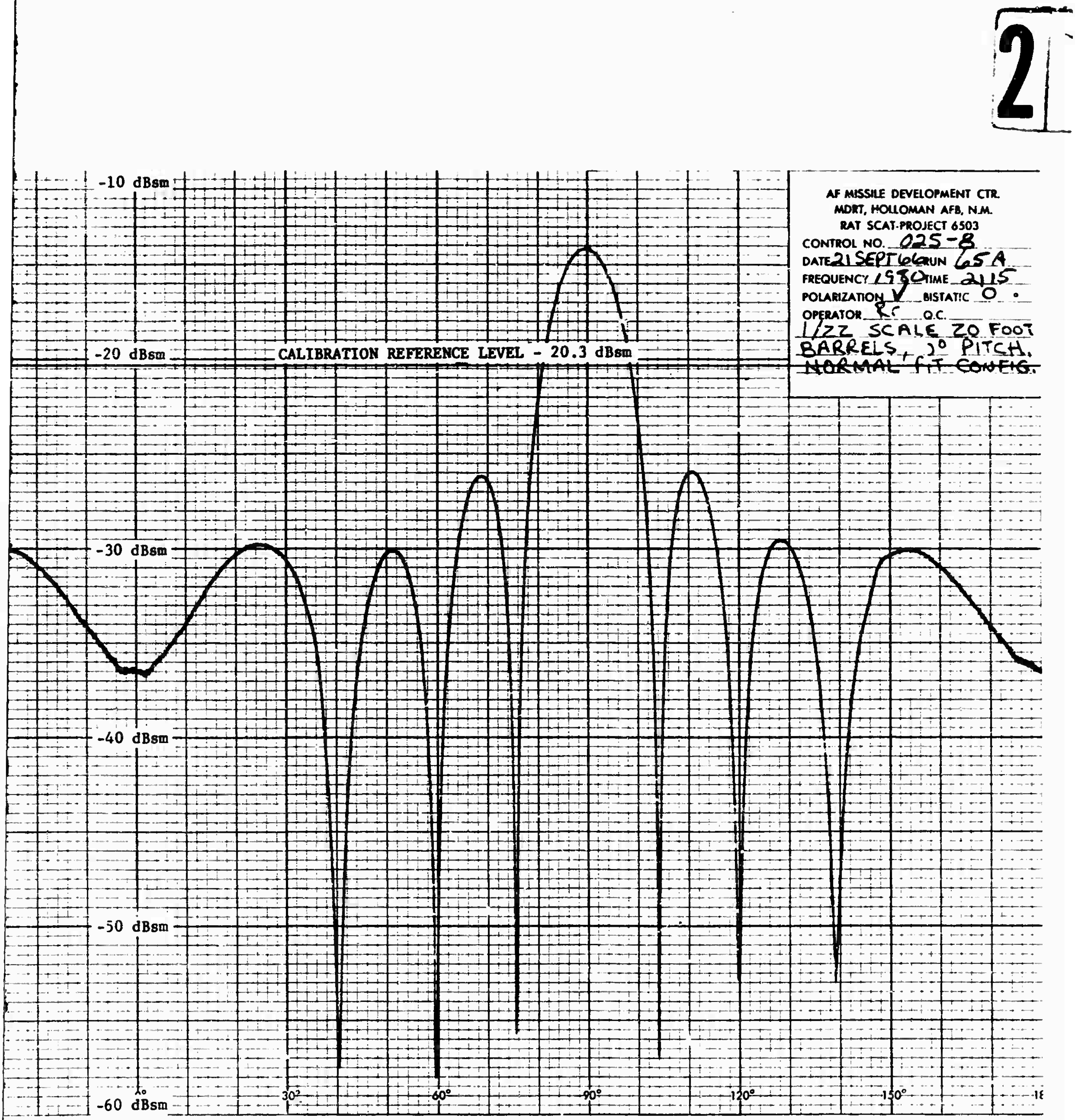

2
-10 dBsm
-20 dBsm
CALIBRATION REFERENCE LEVEL - 20.3 dBsm
-30 dBsm
-40 dBsm
-50 dBsm
-60 dBsm
30°
60°
90°
120°
150°
AF MISSILE DEVELOPMENT CTR.
MDRT, HOLLOMAN AFB, N.M.
RAT SCAT-PROJECT 6503
CONTROL NO. 025-8
DATE 21 SEPT 66 RUN 65A
FREQUENCY 1980 TIME 2115
POLARIZATION V BISTATIC 0°
OPERATOR RC Q.C.
1/22 SCALE 20 FOOT BARRELS, 2° PITCH, NORMAL FIT CONFIG.

Figure 79

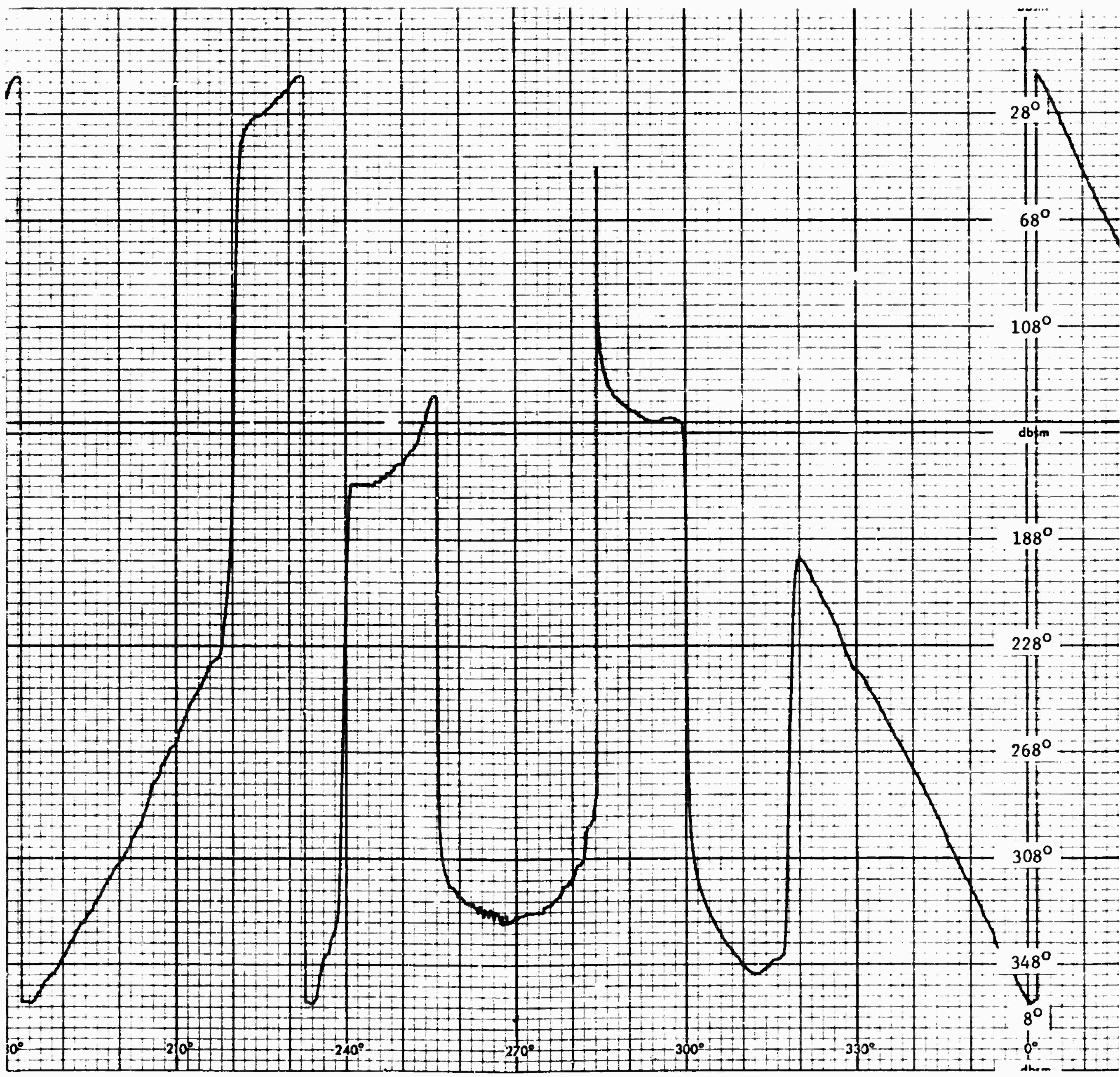
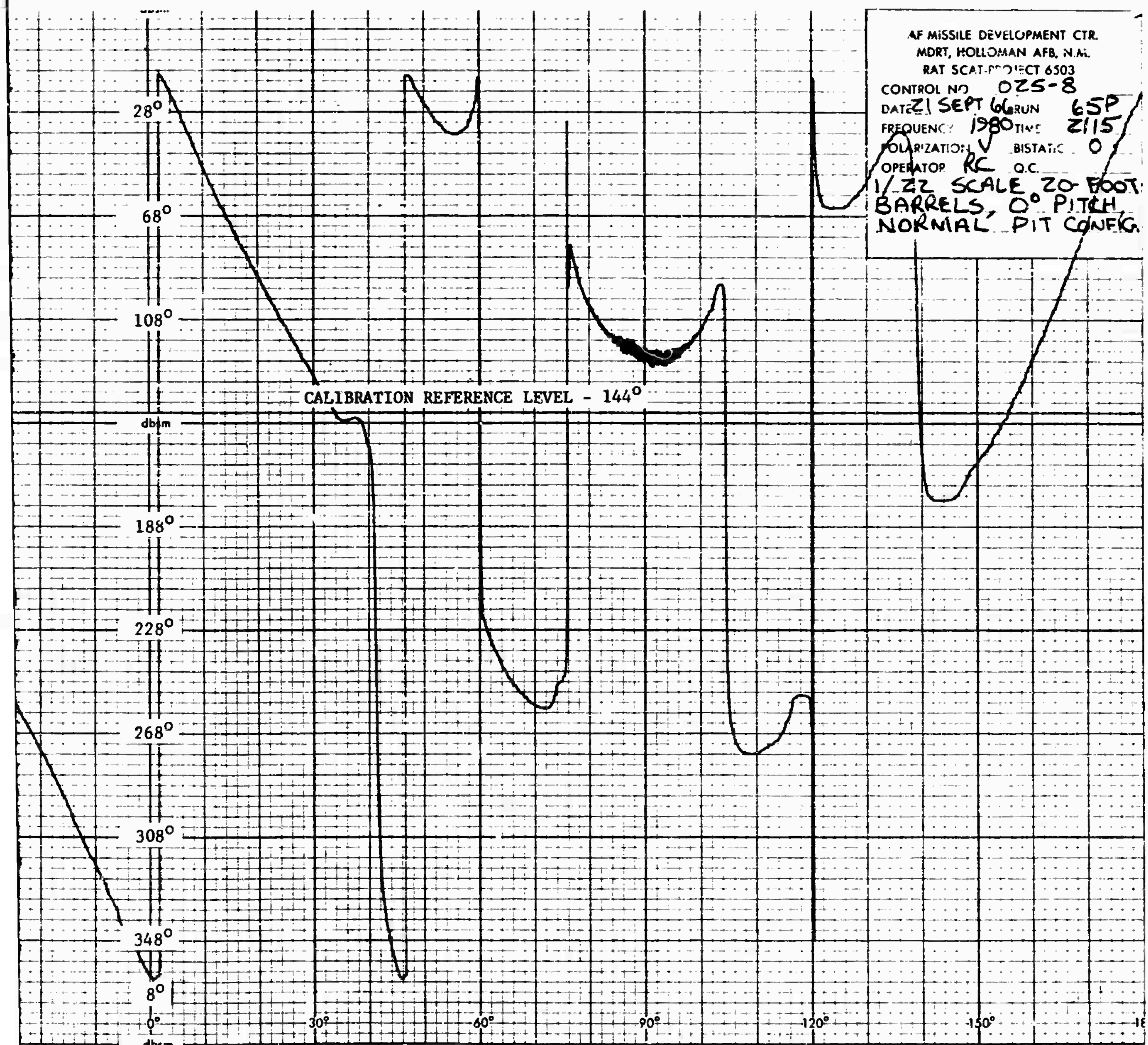
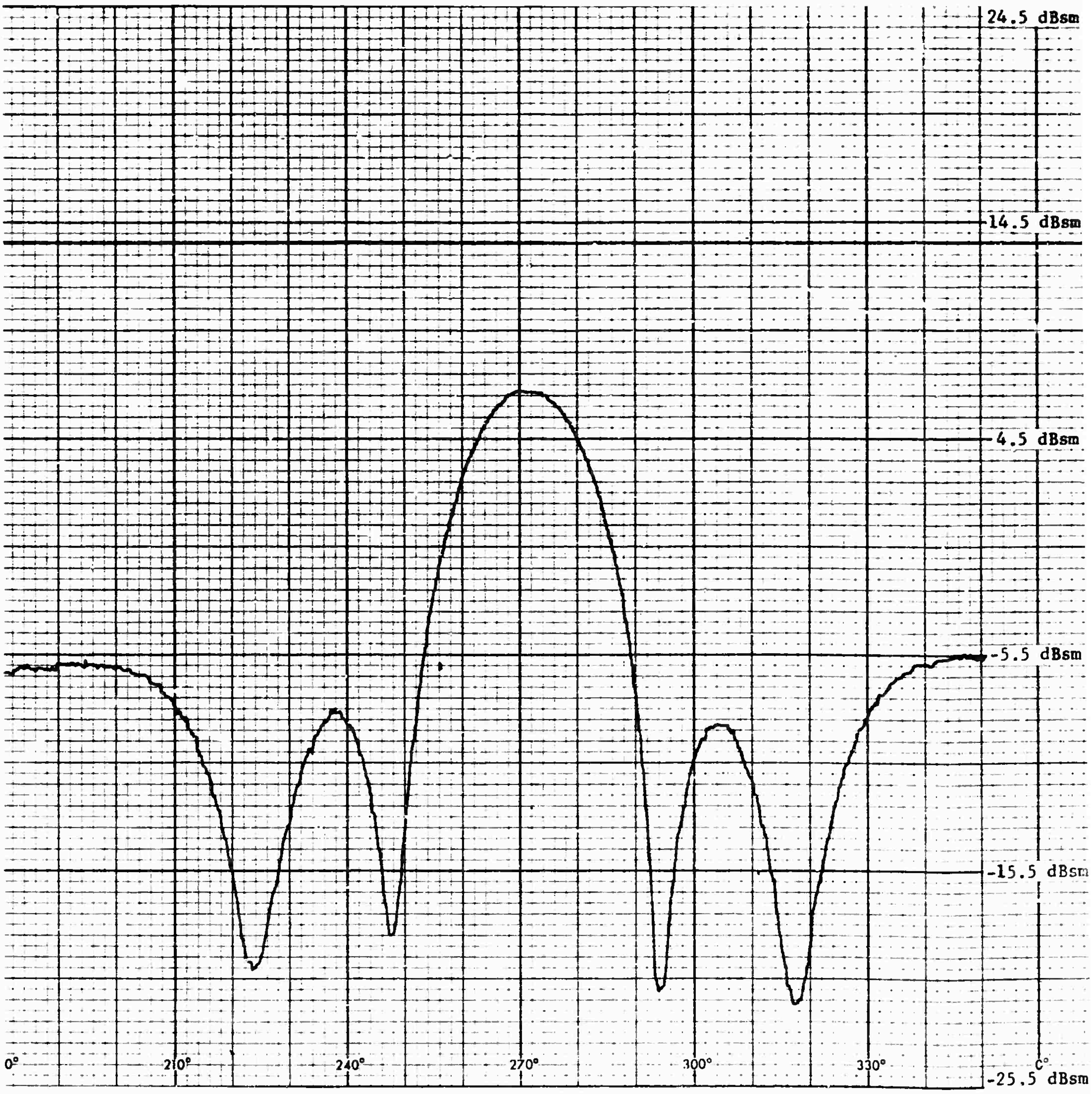


Figure 8

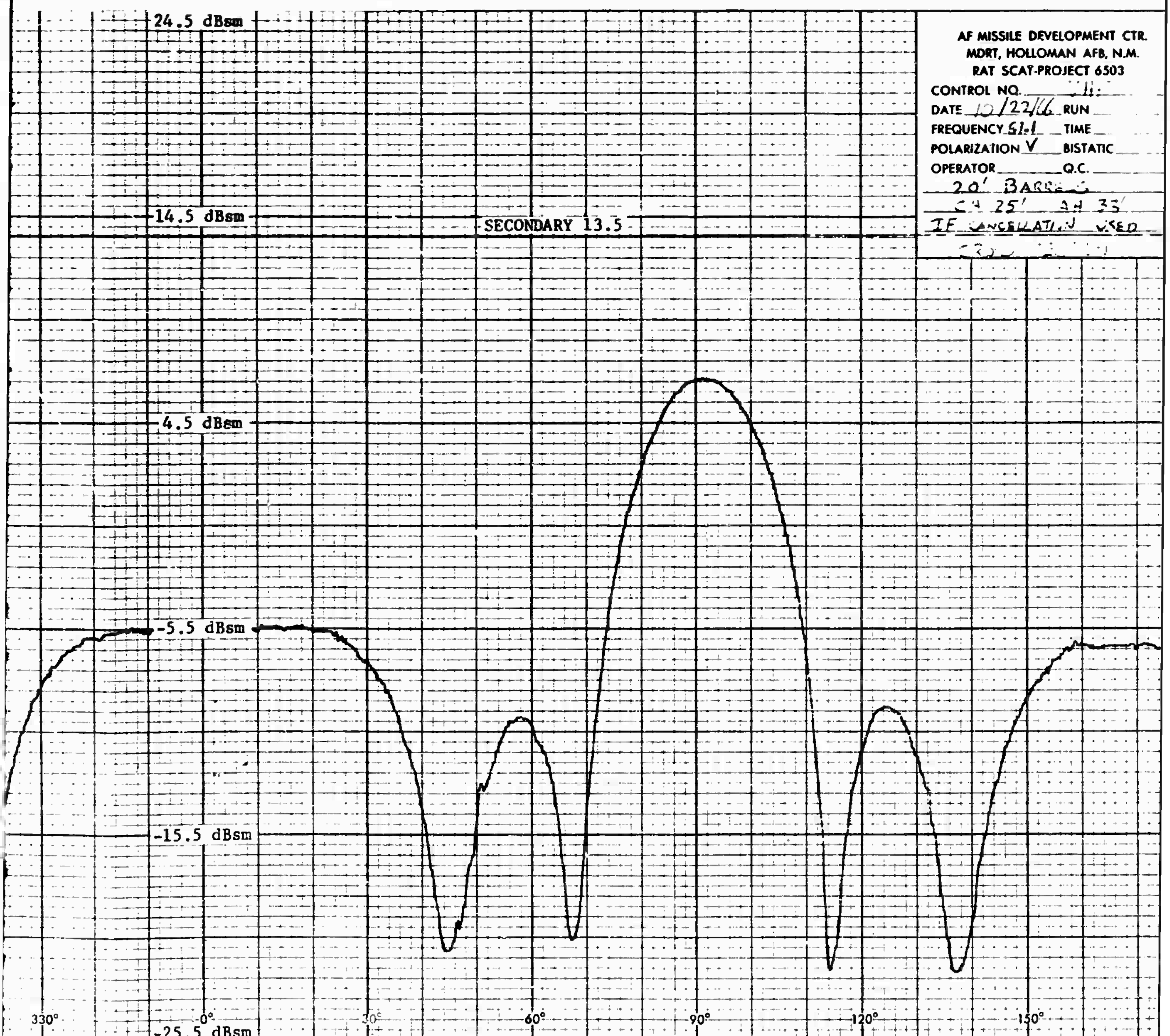


AF MISSILE DEVELOPMENT CTR.
MDRT, HOLLOMAN AFB, N.M.
RAT SCAT-PROJECT 6503
CONTROL NO 025-8
DATE 21 SEPT 66 RUN 65P
FREQUENCY 1980 TIME 2115
POLARIZATION V BISTATIC 0
OPERATOR RC Q.C.
1/22 SCALE 20 FOOT BARRELS, 0° PITCH, NORMAL PIT CONFIG.
CALIBRATION REFERENCE LEVEL - 144°
28°
68°
108°
dbsm
188°
228°
268°
308°
348°
8°
0°
30°
60°
90°
120°
150°

2


24.5 dBsm
14.5 dBsm
4.5 dBsm
-5.5 dBsm
-15.5 dBsm
-25.5 dBsm
0°
210°
240°
270°
300°
330°
0°

2



AF MISSILE DEVELOPMENT CTR.
MDRT, HOLLOMAN AFB, N.M.
RAT SCAT-PROJECT 6503
CONTROL NO.
DATE 10/22/66 RUN
FREQUENCY 51.1 TIME
POLARIZATION V BISTATIC
OPERATOR Q.C.
20' BARREL
IF CANCELLATION USED
24.5 dBsm
14.5 dBsm
SECONDARY 13.5
4.5 dBsm
-5.5 dBsm
-15.5 dBsm
-25.5 dBsm
330°
0°
30°
60°
90°
120°
150°

Figure

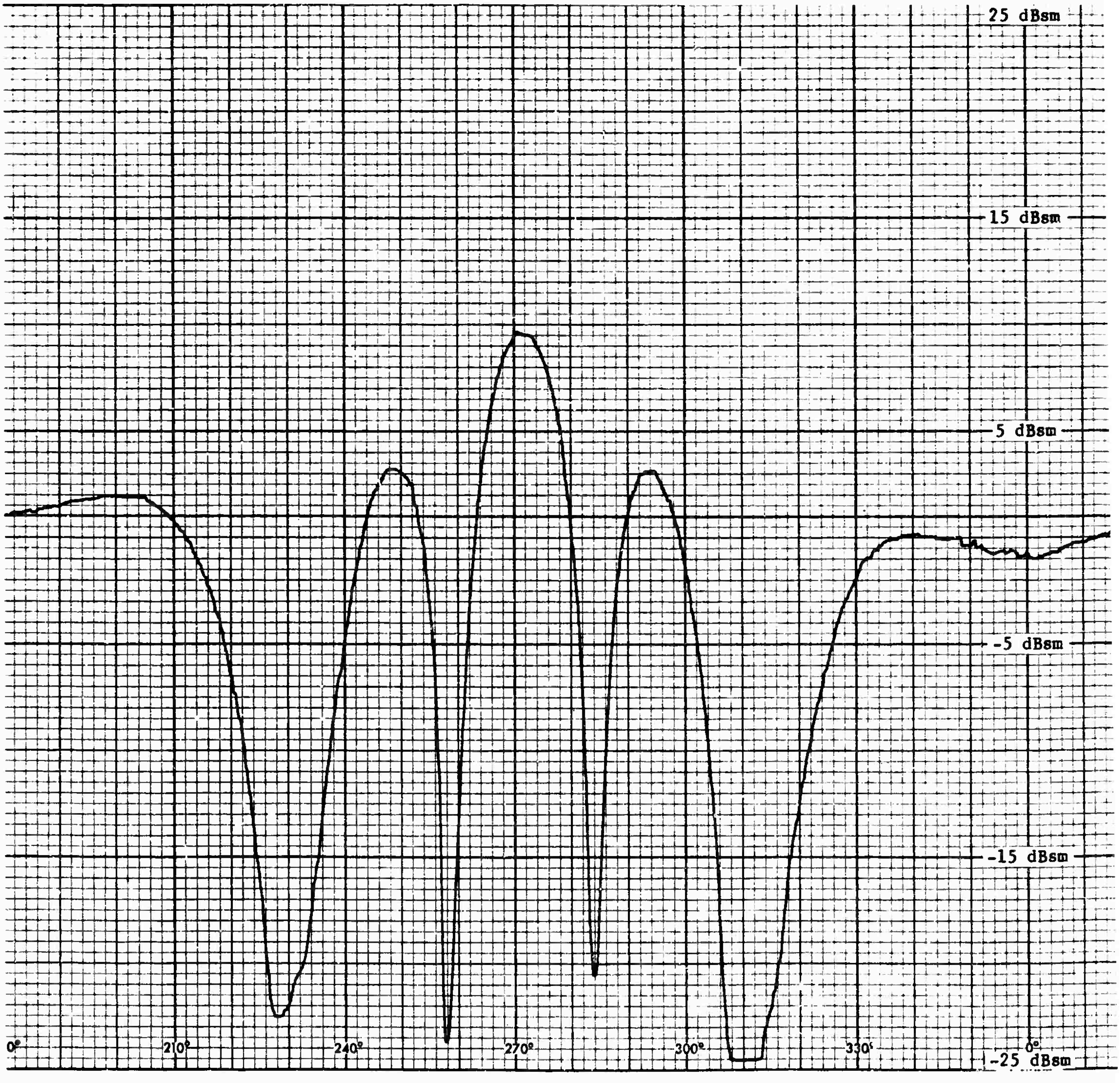
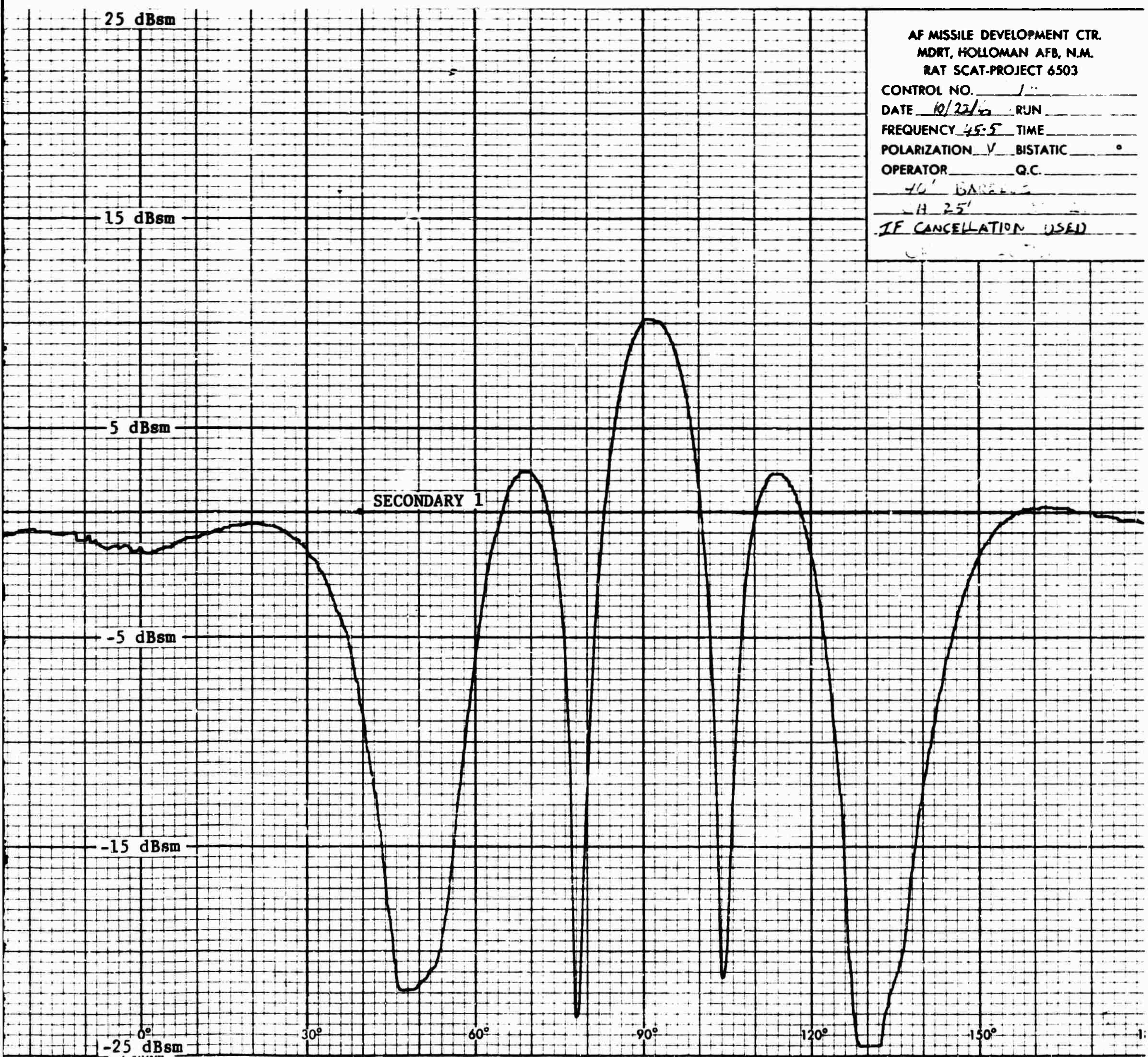

25 dBsm
15 dBsm
5 dBsm
-5 dBsm
-15 dBsm
-25 dBsm
0°
210°
240°
270°
300°
330°
0°

Figure 82


25 dBsm
15 dBsm
5 dBsm
-5 dBsm
-15 dBsm
-25 dBsm
SECONDARY 1
0°
30°
60°
90°
120°
150°
AF MISSILE DEVELOPMENT CTR.
MDRT, HOLLOMAN AFB, N.M.
RAT SCAT-PROJECT 6503
CONTROL NO.
DATE
RUN
FREQUENCY 45.5
TIME
POLARIZATION V
BISTATIC
OPERATOR
Q.C.
IF CANCELLATION USED

2

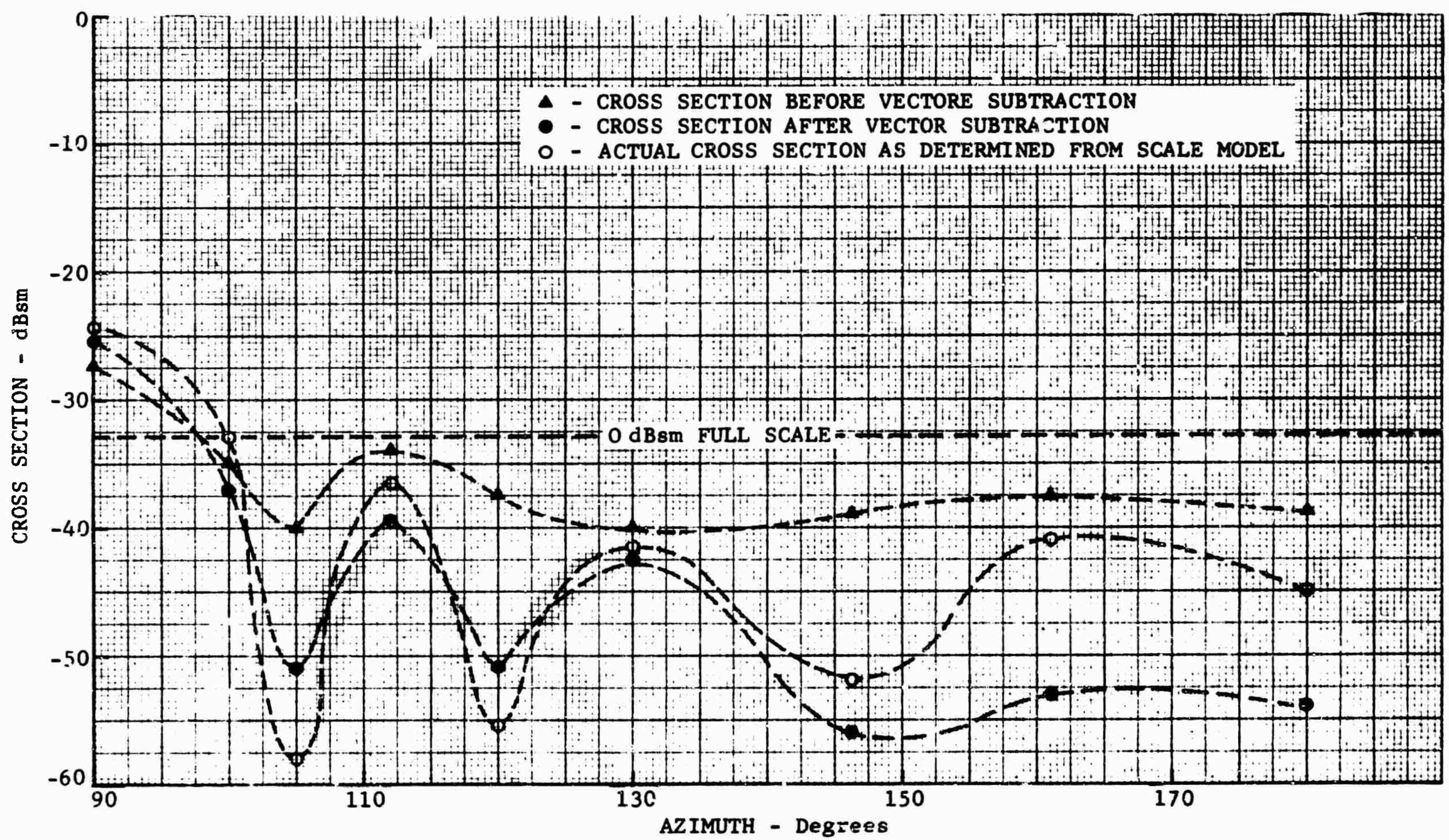


Figure 83. 40-FOOT CYLINDER CROSS SECTION AFTER VECTOR SUBTRACTION AT 45.5 MHz)

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VHF DEMONSTRATION PROGRAM

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13. ABSTRACT

The material presented herein are the results obtained from the successful demonstration of the feasibility of making radar cross section measurements in the VHF band at the Radar Target Scatter Site (RAT SCAT), White Sands Missile Range. Included herein are the results of a Phase Two Field Demonstration program conducted in the 30- to 100- megahertz band for the purpose of evaluating (1) the feasibility of using the electronic systems, built during this program, at RAT SCAT in the VHF band, and (2) the range geometry configurations resulting from the Phase I Computer Study program relative to their utility in an operational system which could be implemented at RAT SCAT.

A test program was defined by which the electronic system, antenna system, range designs, and target supports were evaluated. The coherent electronic system design was such that both CW and pulsed operation was possible. The design included a RF cancellation network for CW short range operation and an IF cancellation network for pulsed operation at longer ranges. Both a single antenna-hybrid system design for use with a short range design and a dual-antenna system design for use at the longer range were implemented and tested. A range length of 350 feet was used to evaluate the short range CW cancellation technique and a range of 1500 feet was used to evaluate the pulsed technique. Test frequencies of 30,45.5,61.1, and 92.2 megahertz were used to obtain information relative to (1) transmitter and receiver performance, (2) single antenna hybrid isolation,(3) dual antenna isolation, (4)RF field gradients,(5)background levels,(6)cross section measurement capability, and (7) feasibility and requirements for adopting the electronic system and range designs into an operational system at RAT SCAT.

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14 KEY WORDS	LINK A ROLE	LINK A WT	LINK B ROLE	LINK B WT	LINK C ROLE	LINK C WT
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Full scale targets						
Radar Cross Section						
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